EFFECT OF CALCIUM EXCHANGE CAPACITY ON THE PROPERTIES OF BLACK COTTON SOIL

A thesis

Submitted

by

Pendela Venkata Naidu

(213CE1048)

In partial fulfillment of the requirements for the award of the degree of

Master of Technology
In
Civil Engineering
(Geotechnical Engineering)
Department of Civil Engineering

Department of Civil Engineering
National Institute of Technology Rourkela
Odisha, -769008, India
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Under the guidance

Of

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May 2015

NATIONAL INSTITUTE OF TECHNOLOGY
ROURKELA, ODISHA-769008
DEPARTMENT OF CIVIL ENGINEERING

CERTIFICATE

This is to certify that the thesis entitled, "***Effect Of Calcium Exchange Capacity On The Properties Of Black Cotton Soil***" is submitted by **PENDELA VENKATA NAIDU**, bearing Roll No. **213CE1048** in partial fulfillment of the requirements for the award of Master of Technology degree in Civil Engineering with specialization in "Geotechnical Engineering" during 2013-2015 session at the National Institute of Technology, Rourkela is an authentic work carried out by him under my supervision and guidance.

To the best of my knowledge, the matter embodied in the thesis has not been submitted to any other University/Institute for the award of any degree or diploma.

Date: 27-May-15
Place: NIT Rourkela

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.

PENDELA VENKATA NAIDU

213CE1048

GEOTECHNICAL ENGINEERING

DEPARTMENT OF CIVIL ENGINEERING

NIT ROURKELA

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ABSTRACT

This research work presents the efficacy of Calcium chloride and fly ash as an additive in improving the engineering properties of Black cotton soil which is expansive soil. Calcium chloride of 1%, 2% and 3% were mixed with black cotton soil used in the laboratory experiments. The fly ash percentages of 20% and 30% were used for compare the results obtained with calcium chloride percentages. The effectiveness of the calcium chloride and fly ash tested by conducting unconfined compressive strength and swelling pressure test. The unconfined compressive test has done for curing period of 7, 14, and 28 days to compare the results with 0 days unconfined compressive strength. The soil samples were subjected to wet and dry cycles and observed that increase of unconfined compressive strength and reduction of swelling pressure. The results were obtained from calcium chloride mixes soil sample after wet and dry cycles has better strength, less swelling pressure and less swelling index

Chapter -1

INTRODUCTION

1.1 Black cotton soil

Black cotton soils are the swelling soils or shrink swell soils which have tendency to shrink or swell with the changes of moisture content. Expansive soils are predominant in many parts of the world. The variation of water content lead to cracking of the structures which built on them. These problems due to expansive soils causes billions of dollars for their repair annually (Nelson and Miller). These expansive behavior not only causes the loss of property but also lost of the lives. The state Texas was used more than 1 billion dollars for the restore the foundation of the buildings, buried utilities, highways and pavements of airports, and embankments which constructed on expansive soils. These soils also called regur soils in some parts of the world.

Over the past 30 years enormous research were executed on the reduction of swelling behavior of expansive soils. Based on methods available for soil stabilization it can be divided into physical mechanical and chemical stabilization. Using different chemical admixtures the stabilization of black cotton soil is commonly adopted in India. Among various chemicals available the most commonly used methods are fly ash stabilization, lime stabilization and cement stabilization.

Black cotton soils are vastly spread in the regions of middle India Andhra Pradesh, Madhya Pradesh, Gujarat, and Maharashtra and in some places of Orissa, expansive soils are available in the regions of Narmada, Tapi, Krishna, and Godavari. In north western India the depth of availability of black cotton soil is very high. The black cotton soils are the residual soils formed due to weathering or chemical decomposition of the rock, left at that place itself after formation from the rocks. The black cotton soils consist of high percentage of montomorollonite content which is responsible for expansion and shrinkage of the soil. Presently at India nearly 25% of the soils are covered by the expansive soils. These soils are having affinity to hold large moisture content so suitable for the growing of the crops like jower, oilseeds, citrus fruits, cereals, sugarcane and vegetables. Black cotton soils are very profitable for the forming and problematic to the constructive point of view.

The wetting and dry of the black cotton soils causes the swelling and shrinkage of the soils which causes progressive damage to the structure. The influence of wetting and dry cycle has been well shown by popesco 1980, chen and ma, 1987 subbarao and satya das, 1988. However the wetting and dry cycles does not effect on the chemically stabilized expansive soils.

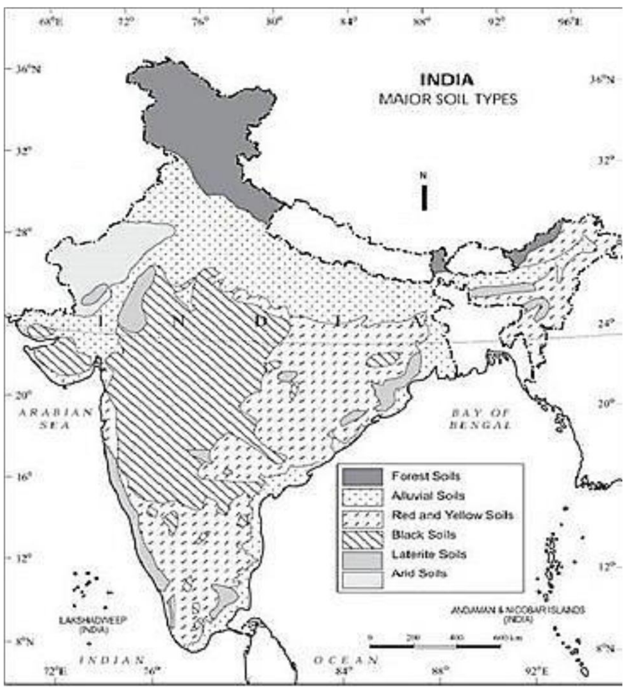

Figure 2.1 soil distribution in India

1.2 Fly Ash

Due to the rapid industrialization and growth of the population the power utilization has increased. The thermal power plants uses coal for production of power, and they grind it to fine powder form, before it is burnt. After burning the coal the mineral residue left, which is collected from the exhaust gases by electro static precipitators. From this whole process the waste material is produced is called fly ash. The main problem with fly ash is safe management and disposal.

Safe disposal and management of fly ash are the causing great difficulties because it occupies vast area of land and it will easily spared around then causes the pollution. The wastes which are generated from the industries having the harmful and very complex chemicals and it is very difficult to treat them so the disposal and management of the fly ash is very crucial point. The fly ash disposal is such way that it do not harm to ecological system and life. So it is needed to treatment before disposal to environment.

Size fly ashes are very small sized particles which mainly having of silica content,alumina content, and iron content. Fly ash particles are rounded in shape and very small size, so it would be easy to mix and to make the desirable mixes. Ashes having both amorphous and crystalline nature of minerals which helps gaining strength when it mix with soil. The type fly ash totally depends on the coal used in the thermal power plant and also it is depend on the industry. Normally most of the fly ash formed from the thermal power plants only.

1.2.1 Fly ash production and environmental disposal

It is known that for making the high temperature steams we normally coal is utilized as a fuel in power production thermal power stations. In the olden days the coal was in the form big sizes was utilizing to make steam from the boilers, but this method observed to be not effecient, it means it utilize more coal and produce very less energy. So to increase output before using the coal would be pulverized in the grinding machines. Then the powdered coal mass is send into combustion chamber, where it can be burns efficiently and within very less time. The output ash which is waste material is known as fly ash, which is having minerals and it behaves as pozzolonic material. Fly ashes transfer along the exit ways, ashes will be trapped by the electro static precipitators. The economizer will observe the heat generated from fly ashes and and gases. While this process is going on, the heat of fly ashes decreased instantly. If the heat reduced instantly, the fly ashes are produced very fine powder or like glassy material and if the cooling process occurs slowly, the hot fly ashes changes into more crystalline in nature. .

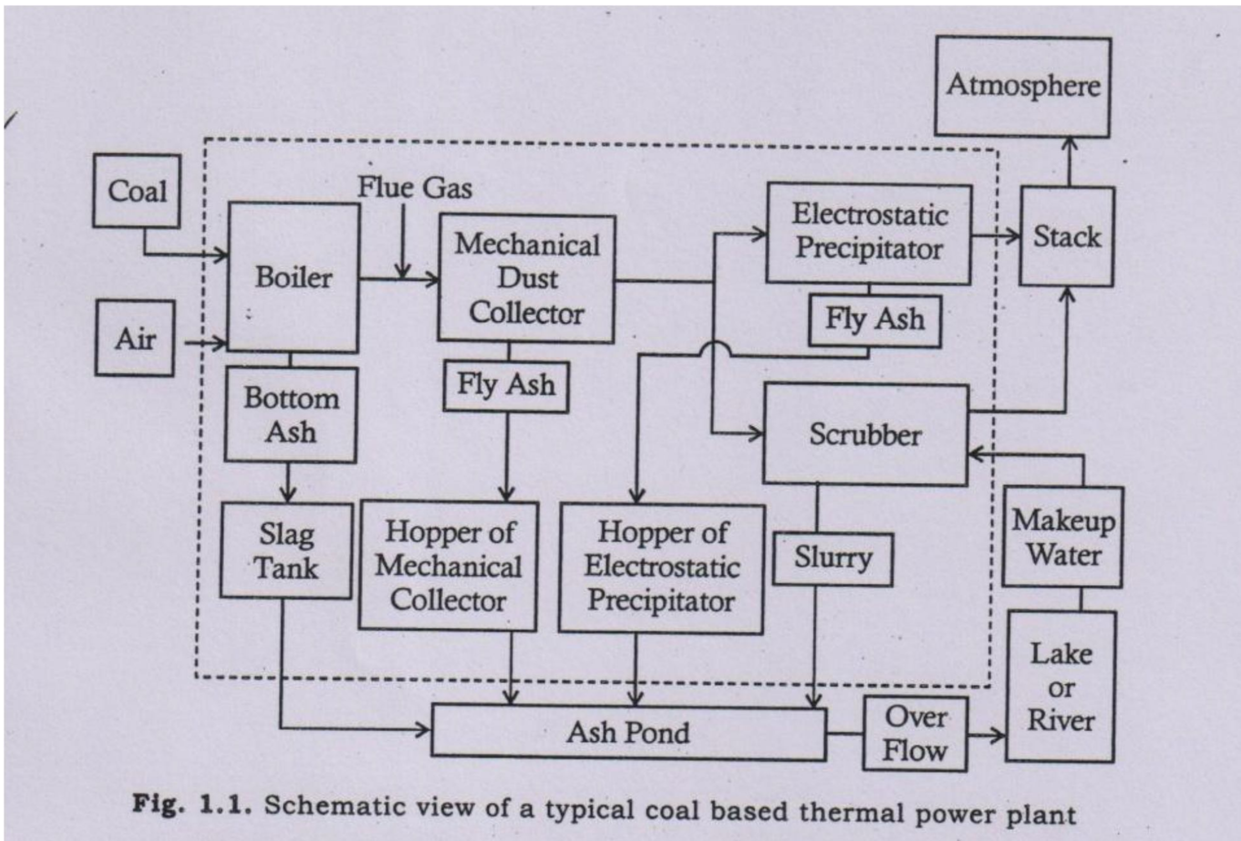

Figure 1.2 schematic view of a typical coal based thermal power plant

The Electro Static Precipitators remove the very small particles so it is commonly adopted in thermal power plants for the removal of fly ash particles. Normally ESPs contains of 4 to 6 chambers, these chambers divide the all fly ash particles from the exit and retains on the chambers as per their size.

Thus if suppose ashes were received from initial chamber, the specific surface area ranges to be 2900 cm2/gm, if suppose the ash is received from second hopper, it is specific area more around 8300 cm^2/gm. The grinded coal will heat, 85% of powders are separated through exit gases and it obtain as powdered form fly ashes, next around 15% ashes, if larger in their size collected in bottom of the plant it is called bottom ash. It is separated in dry form or it is received from water filled chamber, from the down of the furnace. When required amount of bottom ash filled the hopper, it is transported by water jets or water sluice to a disposal pond, where it is called as pond ash.

Country	**Fly ash production per year MT**	**Fly ash use in %**
INDIA	132	57
CHINA	105	46
GERMANY	42	86
ASTRALIA	11	87
FRANCE	4	86
ITALY	3	100
USA	78	64
UK	17	52
CANADA	7	77
DENMARK	3	100
NETHERLAND	4	100

Table 1.1 fly ash production and usage in world wide

The data shown in top, the fly ash in our country currently utilization around 57% in the year 2011-13, then remaining fly ashes moves as a waste material which causes environmental problems. Now, it is time to utilize total fly ash generation, by keeping mind its adverse effect on eco system. To use fly ash total production utilization, world countrys declared 2nd world summit on 2012 for fly ash use. The mission is also getting some knowledge, information about answer for increase of suitable utilization of fly ash. The well maintained coal use, concentrated on its bulk use.

Fly ash use in India	% of use
Dykes	36
Cement	28
Ground improvement	16
Construction	16
Miscellaneous	4

Table 1.2 fly ash utilization in India

1.3 Pore Water

In the present study water is mixed for .different proportions of calcium chloride to determine the engineering and index properties of the soil. Calcium and chloride together form calcium chloride. It is a strong electrolyte and it is behaves as ionic halide. And it is solid at room temperature and highly soluble in water. It is mainly used for brine in refrigerators and Because of hygroscopic nature it control the dust on pavements. anhydrous calcium chloride must keep in such way that air should not be allowed. Calcium chloride is white crystalline compound soluble in water and in soluble in alcohol and kerosene.it is very essential chemical in industrial and manufacturing factories

Calcium chloride is a strong electrolyte and different proportions of calcium chloride is used in the present study and determined behavior of the black cotton soil subjected to wet and dry cycling. The reference solution is used is deionized water. Egolffstein(2002) has given that naturally found calcium chloride in soil ranges between 00.001 to 0.004M (50–170 mg/L Ca^{2+}). The higher concentration of calcium chloride found in the soils having gypsum and slightly soluble minerals found in some natural soils.

Calcium chloride act as source of calcium ions in an aqueous solution. It is soluble in water, yhis property useful changing ions from the water. For example

$$3CaCl_{2\,(aq)} + 2\,K_3PO_{4\,(aq)} \rightarrow Ca_3\,(PO_4)_{2(s)} + 6\,KCl_{(aq)}$$

$$CaCl_{2(l)} \rightarrow Ca_{(s)} + Cl_{2(g}$$

When the calcium chloride used in swimming fools it increases the hardness of water. The main use of this calcium chloride decreases erosion of concrete in swimming pools.

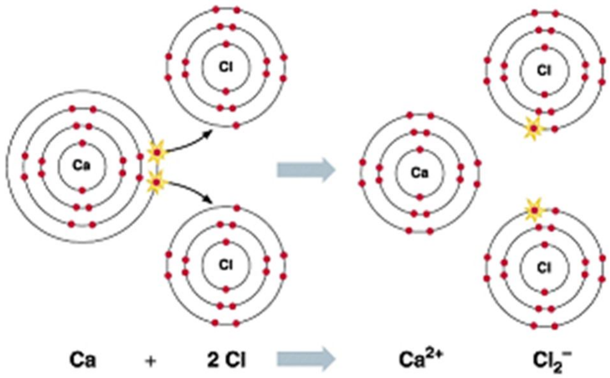

Figure 1.3 calcium chloride formation

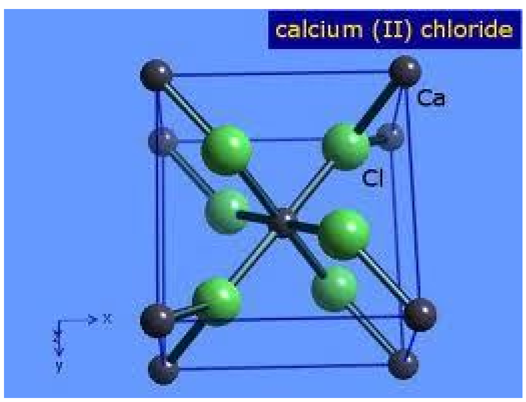

Figure 1.4 structure of calcium chloride

Chapter-2

LITERATURE SURVEY

2.1 Stabilization using chemicals

Ramdas.T.L, et al. (2012) was studied stabilization of expansive soil using calcium chloride. They used different proportions calcium chloride and found out the strength and durability propertied of soil. They were added 0.5, 1,2and 2.5% calcium chloride to the soil and found the consistency limits, unconfined compressive strength and swelling behavior of the soil. They observed addition of calcium chloride increases the unconfined compressive strength and decreases the swelling behavior of the soil and also decrease in liquid limit and increase in plastic limit. They were determined ucs strength improvement for the curing period of 14 and 28 days. From the results, the optimum dosage of $CaCl2$ noticed is 1% by dry weight of soil.

Ramesh.H.N, et al. (2011) due to the contamination of various acids in soils leads to changes of geotechnical properties of soil. Compaction characteristics of the black cotton soil treated with alkali studied and it was found that the density of the soil has improved and optimum moisture content has decreased and also strength propertied of the soil has been improved. Calcium carbonate more effective to the black cotton soil in strength improvement point of view compared to the shedi soil. Contamination of optimum percentage of alkalis treated soils by 1N acids reduced the dry density and increased the optimum moisture content for Black cotton soil while reducing the dry density and moisture content for Shedi soil. From the laboratory study it is known that alkalis of15% and 5% respectively for Black Cotton soil and 15% in case of Shedi soil are effective. Effect of 1N $H2SO4$ is more negative compared to 1N $H3PO4$ on the alkalis treated soils.

Since past few years attention has been given to the acidification and alkalization of the soils to understand physicochemical and engineering properties. Acid rain, industrial effluents, ground water contamination, leachate from landfills and chemical spillages are the sources of acids and alkalis. The effect of Sulphuric acid (H_2SO_4) and Orthophosphoric acid (H_3PO_4) with Calcium Carbonate ($CaCO_3$) and Magnesium Carbonate ($MgCO_3$) treated with black cotton soil and red earth has studied and found the improvement in the soil characteristics. Based on the compaction test it is found that 15% and 10% are optimum percentages of $CaCO_3$ and $MgCO_3$ respectively. It has been observed that Liquid limit of $CaCO_3$ and $MgCO_3$ and with $CaCO_3$ is decreased. Curing effect increased the liquid limit and Plastic limit. Shrinkage limit has been increased with increase in $CaCO_3$ and has been decreased with increase in $MgCO_3$. The Curing effect s reduces Shrinkage limit with $CaCO_3$ and sudden increase with $MgCO_3$. The proctor dry density is rises at optimum percentages of $MgCO_3$ and $CaCO_3$ mix with their optimum moisture content is increased and decreased respectively. Adding acids to the $CaCO_3$ and $MgCO_3$ treated Red Earth showed decrease in maximum dry density and marginal decrease in optimum moisture content. However the bad effect of Sulphuric acid is more on index and compaction properties than that of Orthophosphoric acid.

Sivapullaiah P.V, et al. (2010) it is observed that Mineralogy shows an important in the behavior of fine grained soils. Due to addition of acids in pore water causes the sudden change in the geotechnical properties of the soil and also changes in mineralogical structure of the soil. When original mineralogy of the structure affected the properties of the soil get worse. The behavior of soil during and after contamination is quite difficult to find behavior of the soil. It has been observed that type of chemical was contaminated with the soil and type of soil was affected the time period that was contacted with the soil main factors to assess the properties soil.

Abdelmalek Bouazza (2006) in land field cover system the clay liner may badly subjected to the cations such as magnesium, sodium and aluminum changes the properties of bentonite material if it is subjected to cycles drying and wetting because of continuous rainfall and temperature. To determine the effect of cycles wetting and drying on the liquid limit and plastic limit of the bentonite material and expoansive characteristics of the bentonite were found at different cycles of wet and dry with different proportions of $CaCl_2$ solution used for cycles of wetting and drying. different proportions of $CaCl_2$ mixed at every wetting stage, and determined degree of ion exchange of calcium for sodium on the clay for each stage. However, all others authors investigated behavior of the soil with different proportions of the chemicals and have not been determined degree of calcium exchange achieved. In this they were considered two solutions such as 0.0125M and 0.125M of calcium chloride and determined degree calcium exchange each cycle of wetting. It has also determined that in the laboratory may not possible to achieve the full exchange capacity but in case field it is possible to achieve the full cation exchange capacity. If it is necessary to achieve the full exchange in the laboratory the soil should subjected several wet and dry cycles.

Mohan.S.D.V. et al. (2013) it is not well understood of alkalis and acids on the volume change behavior of soils. Attempts have been made in this paper to study soils treated with optimum percentage of alkalis and contaminated with one normal acids. Results shows that the. The decrease in void ratio for Red earth is small compared to that of BC soil. MgCO3 treated soils with H2SO4 increases the void ratios in marginal differences with CaCO3 treated soils through H3PO4 at all effective pressure. The study shows that the acids effect on the clay mineralogy, because of the acids it effect the compressibility of soil. And also soil behavior depends on the duration of soil interaction with acids.

Abdelmalek Bouazza et al.(2007) it is possible determine the impact cycles of wetting and drying based on exchange, set of three bentonite soil samples were prepared with different proportions of hydrating liquid. The first set test performed using deionized water and used base line of the tests and these results are used to compare with the other results. The second and third sample subjected to 0.0125M and0.125M of CaCl2 to water and performed wet and dry cycling to exchange cations in soil and water. All the samples subjected number of wet and dry cycling before going to the air permeability test. Gas permeability of the bentonite which subjected with 1% calcium chloride solution, was determined that approximately higher than the of the GCL hydrated with de-ionized water, whereas gas permeability test subjected with 0.125M calcium chloride solution was found that higher than the 0.0125M CaCl2 and deionized water.

By Ling-Chu Lin, et.al (2000)liquid limit, plastic limit, swelling index, and permeability tests were performed to determine impact of wet and dry cycling influences the plastic behavior of the soil and swell behavior of expansive soil, and the permeability of expansive clay liners added with water having Ph. value 6.5, tap water having Ph. Value 6.7, and 0.01255-M CaCl2 solvent having Ph value 6.3. So the swelling characteristics of expansive soil added with water enhance at each wetting and drying cycle, the swelling behavior of expansive soil added with water and CaCl2 reduced for every cycles of wet and dry. Wet-dry cycling in Deionized water and tap water had very little effect on swelling of the bentonite which can be negligible.

Ekrem Kalkan (2011) black cotton soils having montomorollenate as main mineral which causes the vulnerable for expansive behavior and shrink properties by varying water percentage. It is also observed that wetting and dry cycle cases the cracks in soil and which leads to increase in the permeability of the soil, which causes distresses to footings, side drainages, and clay liner and side fill for waste nuclear deposits. To reduce the effect of cycles of wet and dry it is necessary to stabilize the soil with some stabilizing agent like chemicals and waste materials. In this study, black cotton soil material mixed using silica fume waste material and also observed. The natural clay sample mixed with silica fume and subjected to several wet and dry cycles and found strength improvement swelling reduction at each wet and dry cycles.

2.2 Stabilizing Using Flyash

Sharma.K.L ***et al*****. (1992)** explained stabilization of the soil using flay ash and other waste material. The material they used were fly ash, gypsum and blast furnace slag. They were used these materials with different proportions for suppose 6:12:18.From the experimental data they found that decreased in the swelling pressure of the soil.

Phani Kumar and Sharma (2004) it is observed that expansive properties of the soil , permeability and swelling properties of the expansive soil decreased with increase flyash content in the soil and it is observed that the dry unit weight and strength increased with increase in fly ash percentage in the soil. It is also observed the resistance against penetration of the soil increased with an increase in fly ash content for given water content. They presented a statistical model to predict the un drained shear strength of the treated soil.

Baytar (2005) it is observed the stabilization of black cotton soils using the fly ash and desulpho-gypsum obtained from thermal power plant varying 0 to 30 percent. Different percentage of lime (0 to 8%) was added to the expansive soil-fly ash-desulphogypsum mixture. The treated samples were cured for 7 and 28 days. It is observed that swelling pressure decreased and rate of swell increased with increasing stabilizer percentage. And also curing of the soil further reduces the swelling of the soil. As the days increases the unconfined compressive strength increases and also swelling potential of the soil decreases.

Phani Kumar and Sharma (2007) it is observed the effect of fly ash on swelling of a highly plastic expansive clay and shrink and swell behavior of another non-expansive high plasticity clay. It is observed the swell potential and swelling pressure, when found at constant dry unit weight of the sample (mixture), reduced by nearly 50% and compression index and coefficient of secondary consolidation of both the clays decreased by 40% at 20% fly ash content.

Chapter-3

MATERIALS AND METHODOLOGY

3.1 Materials

3.1.1Black cotton soil

In the present research, expansive black cotton soil obtained from the geologist, Nagpur, maharashrtra. The black cotton soil was obtained after removing 0.5 m depth top soil by the method of disturbed sampling and transported in sacks to the laboratory. The sample is carefully transported to the laboratory without losing the moisture content to determine moisture content of the soil. The soil is dried and grinded to 4.75 mm sieve to carry out laboratory experiments. The various geotechnical properties shown below.

SL.NO	PROPERTIES	CONFIRMING TO IS CODE	VALUE
1	SPECIFIC GRAVITY	IS 2720:PART 3: SEC1:1980	2.57
2	LIQUID LIMIT	IS 2720:PART 5:1985	75%
3	PLASTIC LIMIT	IS 2720:PART 5:1985	27%
4	OMC	IS 2720:PART VII: 1980	25.10%
5	MDD	IS 2720:PART VII:1980	1.56g/cc
6	UCS	IS 2720:PART 3:1980	26.58 N/cm2
7	NATURAL MOISTURE	IS 2720:PART 2:1973	9.2%
8	FREE SWELL INDEX	IS 2720:PART XL:1977	75
9	SWELLING PRESSURE	IS2720:PART XLI:1977	5.2kg/cm2

Table 3.1 physical properties of black cotton soil

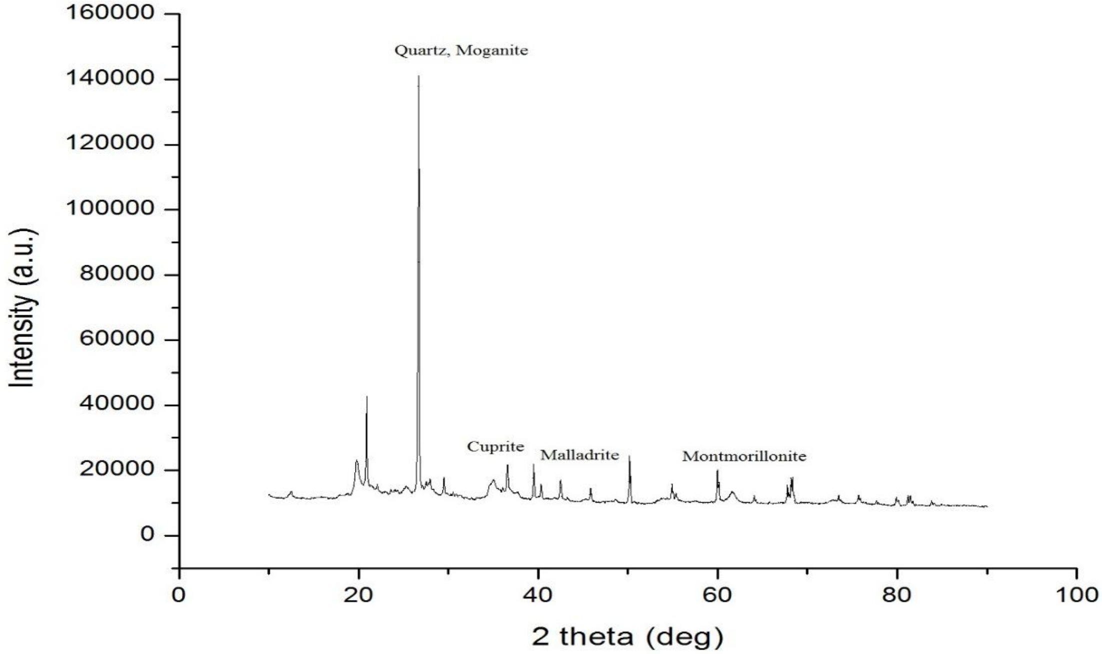

Figure 3.1 XRD Analysis of black cotton soil

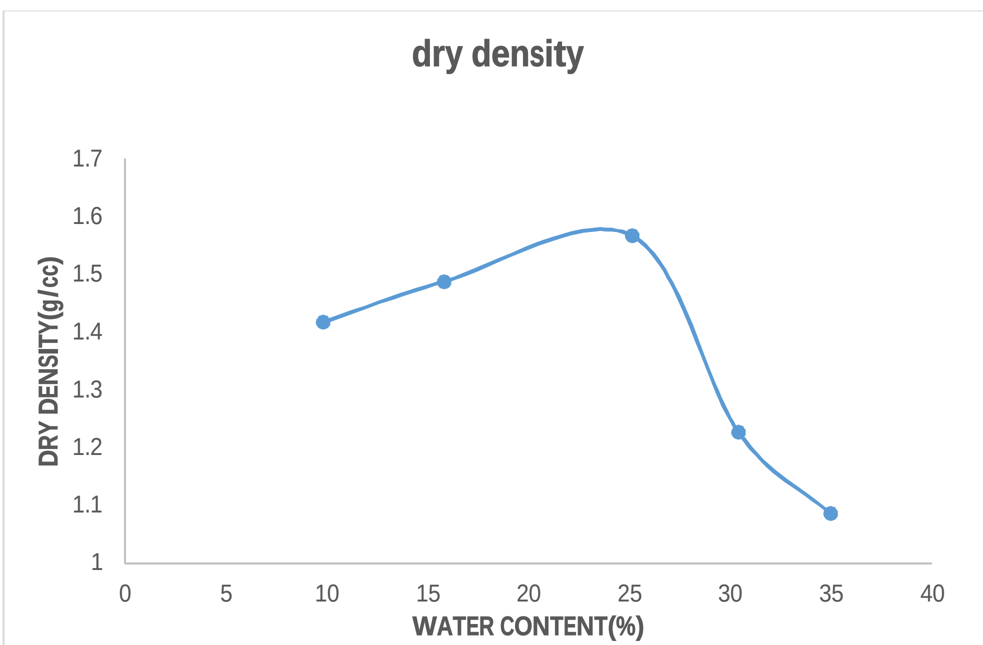

Figure 3.2 Standard proctor curve of black cotton soil

3.1.2 Calcium Chloride

The calcium chloride for this present investigation bought from the Rourkela chemical shop.it has molecular weight 110.47 grams. It is in white crystalline powder form. And also observed that when it is mixed with water it generated heat and also water looks like densified liquid. In the present investigation different proportions of calcium chloride mixed with water and found out the behavior of the soil. Normally expansive soil swells due to the formation of double layer of water in the soil, when we mix with calcium chloride to the soil, it has high affinity to take cation exchange compared with the water. So whenever we add calcium chloride mixed water to the soil, firstly calcium chloride replaces anions in the soil as maximum as possible and water also forms bond but it is observed the thickness of the double layer reduces which helpful to reduction of expansion and swelling pressure.

From the literature survey it is known that the expansive behavior of the soil totally depend on the amount exchange takes place during the whole process. And it was observed in the case of bentonite as number of cycles increases the exchange capacity of the soil increases. In the present study I found the behavior of the soil with 0 number of wet and dry cycles and then soil subjected 5 wet and dry cycles found the behavior of the soil. From the literature survey it is known that as the number of wet and dry cycles increases the properties of the soil will be modified. As the number of wet and dry cycles subjected the cation exchange capacity of the soil increases, the double bond thickness of the water decreases so expansiveness of the soil decreases.

3.1.3 Fly ash

Fly ash is a byproduct from the thermal coal power plants. It is waste material formed due to the combustion of bituminous coal. It is separated from the outlets by the electrostatic precipitators before the flue gases reach the chimneys of coal fired power plants. Normally the fly ash removed with the bottom ash from the bottom of the furnace jointly known as coal ash. The fly ash behavior is abnormal, though fly ash particles are same size the chemistry behavior and mineralogy of the particle varies from the particle to particle. So there is variation of fly ash behavior from different sources, from same source but with time and with collection point.

Generally fly ash also maintains some unburnt carbon and its main constituents are silica aluminum oxide and ferrous oxide. In dry disposal system, the fly ash collected at the bottom of the mechanical dust collectors and ESPs. From the dry storage silos also fly ashes are collected in closed wagons or moisture proof bags or metallic bins, if the quality of the fly ash is better. The dry fly ash so collected is then transported to the required locations where it is subjected to further processing before its use in many non-geotechnical applications such as cement industry, brick manufacturing and the like.

3.2 Methdology

To evaluate the effect of soil/calcium ration and soil/fly ash ratio of swelling pressure and mechanical strength. Three different types of calcium chloride and two different fly ash ratios were used. The calcium ratios were 1%, 2% and 3% and two different proportions of fly ash uses in the present study. The soil and fly ash were mixed thoroughly before the experimental programs conducted. All the tests were conducted according to the IS code method. The following experiments were conducted in the laboratory.

3.2.1 Wet and Dry Cycles

Black cotton soil specimens were mixed with water and different proportions of calcium chloride solutions and different proportions of fly ash then After Atterberg limits will be measured.

Then the black cotton soil was left to air dry in the laboratory environment (at controlled temperature of 21± 5C) until the loss of moisture ceased. Each black cotton soil specimen was then re-wetted with the same concentration of liquid as used initially.

The soil specimens were tested for up to five wet–dry cycles. In each cycle the behavior of the soil was observed.

TESTING PROGRAM

There are two series of experiments were conducted in this work. The first series of tests conducted to determine the physical and mechanical properties of black cotton soil which includes the index properties of black cotton soil such as the specific gravity, grain size distribution and the consistency indices. And also determined all the compactive behavior at different proportions of calcium chloride and fly ash. The liquid limit and plastic limit were determined at different mixtures of calcium chloride and soil mixtures.

Then the second set of experiments were conducted out to determine the swelling pressure, free swelling and strength properties of black cotton soil. The swelling behavior and strength properties of black cotton were determined by swelling and unconfined test apparatus respectively. In the unconfined compressive test the ratio of soil and calcium chloride were 1%, 2%, and 3%. The effectiveness of calcium chloride at different proportions are determined, it is found that 2% of calcium chloride is effective in the case of strength improvement and swelling behavior. And also it is found that the calcium chloride mix provides better results than soil fly ash mixes. All these specimens were of 50mm diameter and 100mm in length were used in unconfined compressive test.

3.3 Determination of Index Properties

3.3.1 Determination Specific Gravity

The specific gravity is defined as the ratio of density of the given soil solids at a given Temperature (270C) to the density of the distilled water at that temperature, both densities determined at same temperature. The specific gravity is determined by conducting the experiment by using pycnometer as per IS 2720 Part 3 Sec 2 1980. To determine specific gravity dry weight of pycnometer determined. Then 50gm soil added to the pycnometer and determine weight. Then added ¾ of water and mixed by shaking. Then added water up to the mark and determined total weight then the soil was thrown away. Then after cleaned pycnometer determined weight of water up to the mark level.

3.3.2 Grain Size Distribution

percentage of different sizes of soil in a dry soil sample are determined by the sieve analysis which analyses in two stages, that is dry sieve analysis and sedimentation Analysis .The sieve analysis was determined if all soil particles which not passes through the Square opening 75 micron as per IS: 2720 part (IV) and the soil finer than 75 microns hydrometer analysis is conducted as per IS: 2720

3.3.3 Determination of Liquid Limit

The liquid limit experiment conducted according to the code of IS 2720: PART 5:1985. 300 grams of soil sample was taken added water thoroughly. The paste was mixed thoroughly using knife plate for 10 minutes. By using casagrande apparatus liquid limit was determined. After mixing the soil thoroughly, the soil sample placed in the cup. A groove is formed at the center of the soil sample. By using of the crank-operated cam, the cup is lifted height of 10 cm and then dropped. The water content, to the soil, mixes to end the length of 12.7 mm along the bottom of the groove after 25 blows is defined as the *liquid limit.* It is very difficult to make the water content in the soil to get the required 12.7 mm closure of the groove in the soil pat at 25 blows. Hence, at least three tests for the same soil were conducted at different water contents, and noted number of blows, N, required to achieve closure varying between 15 and 35. The water content with respect to number of blows drawn in the semi logarithmic graph and determined water content at 25 number of blows. The graph formed between water content and number of blows almost a straight line. This line known as flow line. The water content at 25 number of blows gives the liquid limit of the soil. The slope of the flow line is defined as the flow index.

	BCS	BCS+1% CaCl2	BCS+2%$CaCl_2$	BCS+3%$CaCl_2$	BCS+20%FA	BCS+30%FA
0CYCLE	76.621	72.25	67.325	66.325	65.857	57.4855
1CYCLE	75.0455	69.416	66.548	65.602	65.4765	58.6175
2CYCLE	75.01	67.035	64.325	63.347	67.4885	58.985
3CYCLE	75.58	65.988	60.365	59.26	66.908	57.985
4CYCLE	75.89	65.12	61.258	57.698	65.958	59.875
5CYCLE	76.52	64.858	58.365	56.36	66.0202	59.685

Table 3.2 Liquid limit in % at different cycles

3.3.4 Determination of Plastic Limit

The plastic limit is defined as the water content at which soil crumble into the 4.5mm threads. The plastic limit is the lower water content of plastic stage. The plastic limit test is easy to determine and is determined by continuous rollings of soil mass by hand on a ground glass plat. The procedure for plastic limit was followed according to ASTM.

For the present investigation different proportions of calcium chloride and different proportions of fly ash were used. Liquid limit and plastic limit was determined for all the proportions and compared the results.

	BCS	BCS+1%$CaCl_2$	BCS+2%$CaCl_2$	BCS+3%$CaCl_2$	BCS+20%FA	BCS+30%FA
0 CYCLES	27	32	38	39	23	21
1 CYCLES	28	34	39	40	24	21
2CYCLES	27	35	40	41	24	22
3CYCLES	28	36	40	42	26	23
4CYCLES	28	37	41	43	26	23
5 CYCLES	29	37	42	43	27	24

Table 3.3 Plastic limit in % of the at different cycles

3.4 Compaction Characteristics

Standard proctor test has been done according to the code IS 2720: PART VII: 1980. This test is used to determine the maximum dry density of the soil. In this method first weight the empty mould of base plate attach collar to the plate. Then apply thin layer of grease to the mould. Then take 2.4 kg of the soil and add the water up to 10% of the weight of the soil, Then mix the soil thoroughly. Keep the soil under covered 20 to 30 seconds to allow the soil for full maturation.

Divide the soil into three equal parts and fill the mould with first first and compact it to 25 number of blows. These blows should be evenly distributed whole area of the sample, so that we can achieve the better density. Repeat this procedure second and third part of the soil by taking precaution to scratch the previously compacted soil to achieve the homogenous density throughout depth of the soil. Remove the collar rotating it without disturbing the soil and then scratch the top soil up to the level. Then take the total weight of the soil and mould. Repeat this procedure by taking the fresh soil with varying the water content and determine the density of the soil in each case and then draw the graph between maximum dry density verses water content and then deter mine density of the soil.

The above procedure has been continued for different proportions of the soil and found the density improvement with increase of calcium chloride and also reduction of water content with increasing the calcium chloride content.

	BCS		BCS+1% $CaCl_2$		BCS+2%$CaCl_2$		BCS+3%$CaCl_2$		BCS+20%FA		BCS+30%FA	
	D	OMC	D	OMC	D	OMC	D	OMC	D	OMC	D	OMC
0CYCLE	1.56	25.10	1.578	23.47	1.58	21.33	1.591	21.12	1.54	30.48	1.52	31.29
1CYCLE	1.57	24.23	1.58	22.58	1.60	19.93	1.61	19.74	1.53	29.98	1.521	30.19
2CYCLE	1.578	23.16	1.589	21.86	1.61	19.61	1.62	18.84	1.523	28.32	1.513	27.29
3CYCLE	1.59	22.16	1.592	21.91	1.621	18.72	1.629	18.24	1.521	29.12	1.511	26.91
4CYCLE	1.60	21.92	1.60	20.64	1.627	18.63	1.631	18.12	1.51	28.56	1.50	27.69
5CYCLE	1.601	21.31	1.612	20.61	1.624	17.64	1.63	18.1	1.50	27.56	1.502	26.97

D=Maximum Dry Density In g/cc, OMC=Optimum Moisture Content in %

Table 3.4 Compaction characteristics of black cotton soil

3.5 Unconfined Compressive Test

Unconfined compressive test has been done according to code of IS 2720: PART 3:1980. Unconfined compressive strength load per unit area at which unconfined cylindrical specimen of the soil fail in compression test. It was observed that force per unit area has not been obtained maximum value up to the 20% of the strain.

In the experimental program first it necessary to know the maximum dry density of the soil and optimum moisture content. The main intention of the unconfined compressive strength test is to find the unconfined compressive strength of soil that having enough cohesion to admit for determining in the unconfined state which is then possible to determine unconsolidated and un drained shear strength of the soil. The UCS test is determined as per IS: 2720 (Part 10) 1991.The soil sample was prepared from freshly developed soil sample and laid the samples for 7days in a constant water content desiccator .For purposes of testing black cotton soil specimen we use 5 to 20 KN proving ring depends on the strength of the soil. After knowing the volume of the mould, the soil will be compacted to into the mould up to the maximum dry density and optimum moisture content was used. Then after compacting the soil soil specimen will be removed from the mould which having 5 cm diameter and 10cm height. Then soil sample placed in the compressive testing machine without any side confinement and the stress strain values has been recorded.

In the present experiment I used 5 KN proving ring and noted down the values obtained from the proving ring with changes of strain. I determined unconfined compressive strength for different percentages of calcium chloride and different percentages of fly ash.

% OF $CaCl_2$	UCS(N/Cm^2)
0	26.58
0.5	27.68
1	28.698
1.5	29.685
2	29.987
2.5	30.6548
3	30.96854
3.5	31.0253

Table 3.5 UCS at different percentage of calcium chloride

NO cycles	BCS	BCS+1%$CaCl_2$	BCS+2%$CaCl_2$	BCS+3%$CaCl_2$	BCS+20%FA	BCS+30%FA
0	26.58	27.25	29.21	30.59	28.46	29.31
1	26.98	28.69	30.42	30.79	27.78	30.95
2	27.54	31.05	32.8	34.29	28.99	30.88
3	27.25	32.72	34.55	36.38	29.1	31.48
4	27.25	35.07	37.74	39.52	29.47	31.67
5	27.37	37.43	41.05	42.69	29.73	31.93

Table 3.6 UCS (N/Cm^2)0 Days strength at different cycles

Number of cycles	BCS	BCS+1%$CaCl_2$	BCS+2%$CaCl_2$	BCS+3%$CaCl_2$	BCS+20%FA	BCS+30%FA
0	30.01	32.89	33.94	34.02	32.89	32.72
1	30.48	34.02	34.29	36.31	32.18	34.47
2	30.85	35.07	37.89	42.37	32.45	34.92
3	30.85	36.38	39.52	43.99	32.72	34.55
4	30.69	39.21	41.42	46.33	32.98	34.55
5	30.69	42.14	46.6	49.72	33.42	35.19

Table3.7 UCS (N/Cm^2) 7 days strength at different cycles

NO cycles	BCS	BCS+1%$CaCl_2$	BCS+2%$CaCl_2$	BCS+3%$CaCl_2$	BCS+20%FA	BCS+30%FA
0	32.54	34.29	38.91	41.24	35.33	38.62
1	34.31	36.54	40.12	41.61	36.12	39.21
2	34.66	37.24	40.74	43.45	37.13	40.12
3	34.73	39.83	43.68	45.54	36.21	41
4	35	43.18	46.07	48.16	37.1	39.12
5	34.81	46.59	49.2	51.28	37.21	39.14

Table 3.8 UCS (N/Cm^2) 14 days strength at different cycles

Number of cycles	BCS	BCS+1% $CaCl_2$	BCS+2% $CaCl_2$	BCS+3% $CaCl_2$	BCS+20%FA	BCS+30%FA
0	38.62	38.79	42.31	46.21	41.64	45.32
1	39.21	42.12	44.94	47.23	41.64	44.25
2	39.05	45.02	46.85	48.16	42.32	44.25
3	39.73	47.12	49.47	51.04	43.42	45.28
4	40	50.77	52.32	56.01	43.45	45.28
5	39.78	54.7	57.01	61.05	43.94	45.52

Table 3.9 UCS (N/Cm^2) 28 days strength at different cycles

3.6 Free Swell Test

The free swell test has been followed the code of IS 2720:PART XL:1977. Basically free swell index has been developed in the field to know the expansive and non-expansiveness of the soil. Also determine the expansive percentage of the soil. Bureau of indian standard suggest that the free swell index test should be used for fine grained soil, which is defined as

$$\text{Free swell index} = ((V_d - V_k)/(V_k))*100$$

V_d is the equilibrium sediment volume of 10gm of oven dried sample passed through 425microns and placed in distilled water to expand up to its capacity. V_k is the equilibrium sediment volume of 10 gm of oven dried sample passed through 425microns and placed in kerosene which would not expand at all. By using the above formula it is easy determine the free swelling index of the soil.

In the present experimental program free swell index has been found for different proportions of calcium chloride. It has been observed that soil with calcium chloride has less expansion compared with soil and fly ash mixes.

	BCS	BCS+1%$CaCl_2$	BCS+2%$CaCl_2$	BCS+3%$CaCl_2$	BCS+20%FA	BCS+30%FA
0 cycles	77.27273	72.72727	66.365	65.45455	61.534	57.69231
1 cycles	77.98165	69.72477	61.368	60.55046	61.923	58.294
2 cycles	76.52174	66.95652	57.598	56.52174	62.124	58.289
3 cycles	75	65	55.368	54.1667	62.952	58.721
4 cycles	75	63.3333	53.34	51.66667	63.124	59.724

Table 3.10 Free swelling of the soil at different cycles

3.7 Swelling Pressure Test

The main purpose of this test is to obtain soil data which are used to predicting the rate and amount of swelling pressure. The experimental selling test has done on the consolidometer. Clean the consolidometer and weight it empty. Press the consolidometer ring gradually into the densified soil apparatus to get soil sample and trim the soil in all sides. Compact the soil in the mould after fixing the base porous stone in layers containing the porous stone and collar at top side. Put the porous stone on the top of the soil and fix the top plate which is provided with an inlet valve and air cook. Please assemble the shallow metal tray with and fill the tray with water so that it should be fully submerged in water. After that allow soil expand for 5-7 days, after expansion is over started applying the load on the soil until it reaches its original reading.

The above experiment has been done for different wet and dry cycles and finally found expansion of the soil with different wet and dry cycles

The following results has been observed the laboratory

Results in kg/cm^2

	BCS	**BCS+1%$CaCl_2$**	**BCS+2%$CaCl_2$**	**BCS+3%$CaCl_2$**	**BCS+20%FA**	**BCS+30%FA**
O CYCLE	5.2	4.5	3.2	2.9	4.4	3.9
1 CYCLE	5.2	4.2	3	2.8	4.4	4
2 CYCLE	5.3	4	2.8	2.6	4.5	4
3 CYCLE	5.4	3.9	2.6	2.4	4.6	4.1
4 CYCLE	5.4	3.7	2.5	2.3	4.7	4.1
5 CYCLE	5.5	3.5	2.4	2.2	4.9	4.2

Table 3.11 swelling pressure at different cycles

Chapter-4

RESULTS AND DISCUSSION

4.1 Liquid Limit

Liquid limit has been done according to the code of IS 2720: PART 5:1985. The following graph has been observed.

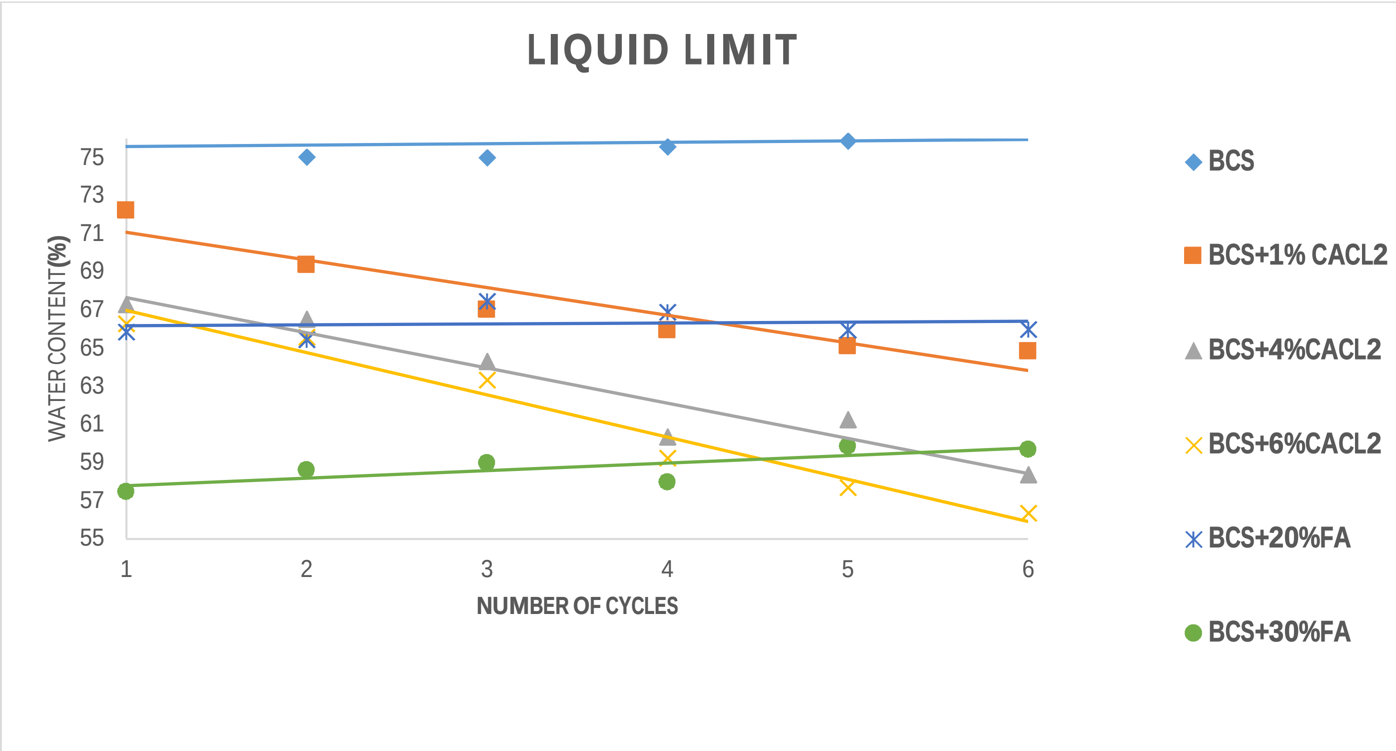

Figure 4.1 Graph between liquid limit and number of cycles

From the above graph it is observed that as the number of cycles of wet and dry increases the liquid limit of the soil decreases only soil mixes with calcium chloride. And also it is found that the calcium chloride with 1% the reduction of liquid limit quite less. With 2% of calcium chloride is effective in the reduction of liquid limit. And also with 3% of calcium chloride it is observed liquid limit little bit less than 2% of calcium chloride. With the fly ash it is observed that as the number of wet and dry cycles increases the liquid limit of the soil increases.

4.2 Plastic Limit

Plastic limit done according to the code of IS 2720: PART 5:1985. The following graph has been drawn.

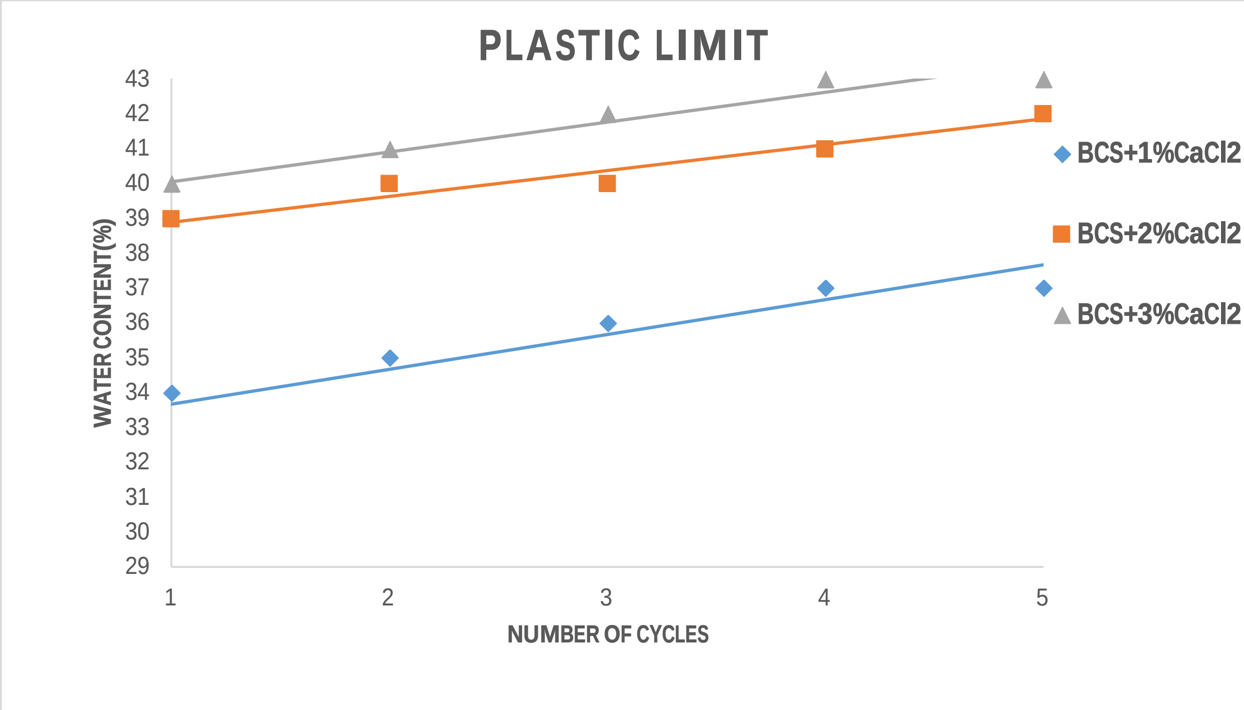

Figure 4.2 Graph between plastic limit and number of cycles

The graph has been depicted for different percentages of calcium chloride. It has been observed that as the number of cycles increases the plastic limit of the soil increases. With the high percentage of calcium chloride. It has been observed that 2% of calcium chloride is optimum percentage for the plastic limit of the soil. As we know that plastic limit of the soil increases plasticity index decreases so the expansive behavior of the soil decreases. And also has been observed with 3% calcium chloride the change of plastic limit is little bit above the 2% calcium chloride mixed soil. So for economical point of view the 2% calcium chloride has been recommended.

4.3 Free Swelling Index

Differential free swell index has been done according to the code of IS 2720: PART XL: 1977. The following graphs has been drawn from the results.

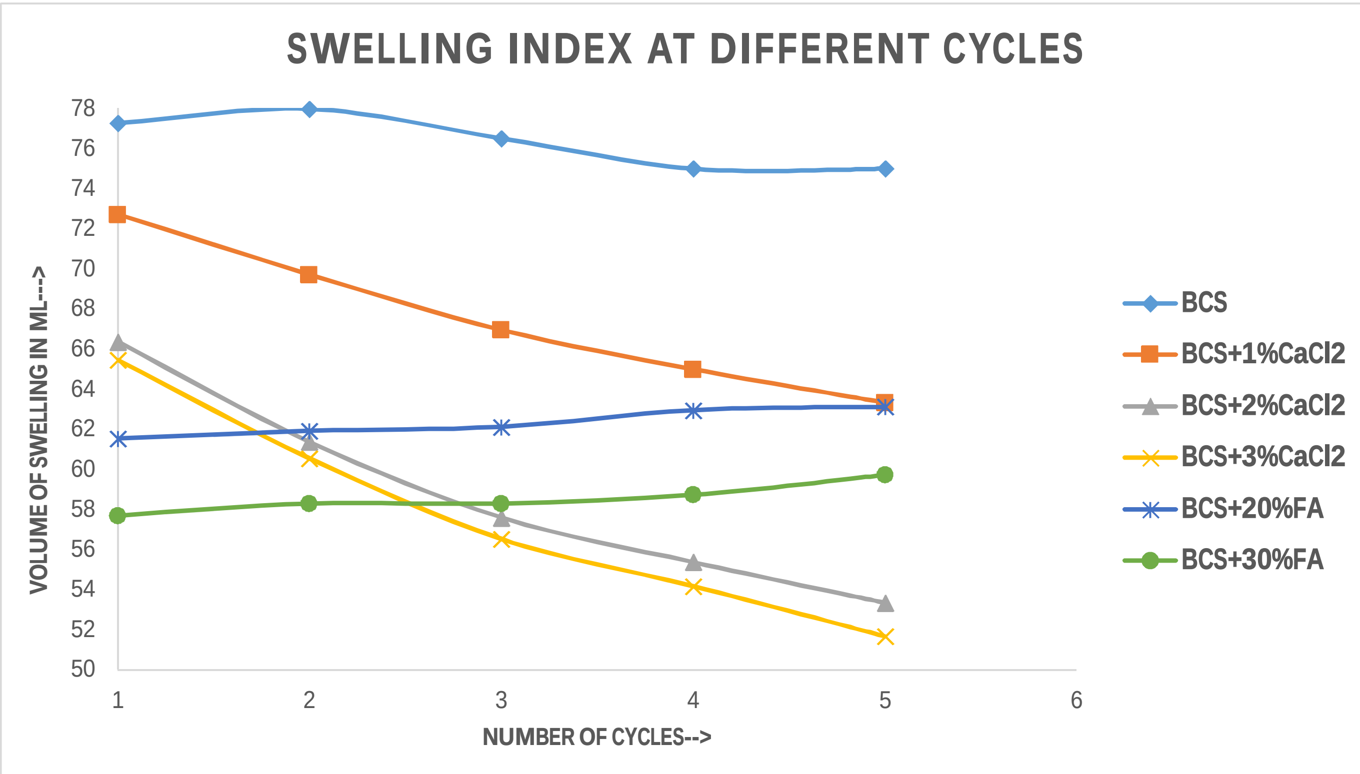

Figure 4.3 swelling index at different cycles

The graph is drawn between volume of swelling and number of cycles. It has been observed from the graph as the number of wetting drying cycles increases swelling of the black cotton soil decreases. And also it is observed that as the percentage of calcium chloride increases the swelling behavior of the soil decreases. For the economical point of view 2% of calcium chloride has been recommended for the stabilization.

4.4 Compaction Characteristics

Standard proctor test has been done according to code of IS 2720:PART VII:1980. The following graphs were observed.

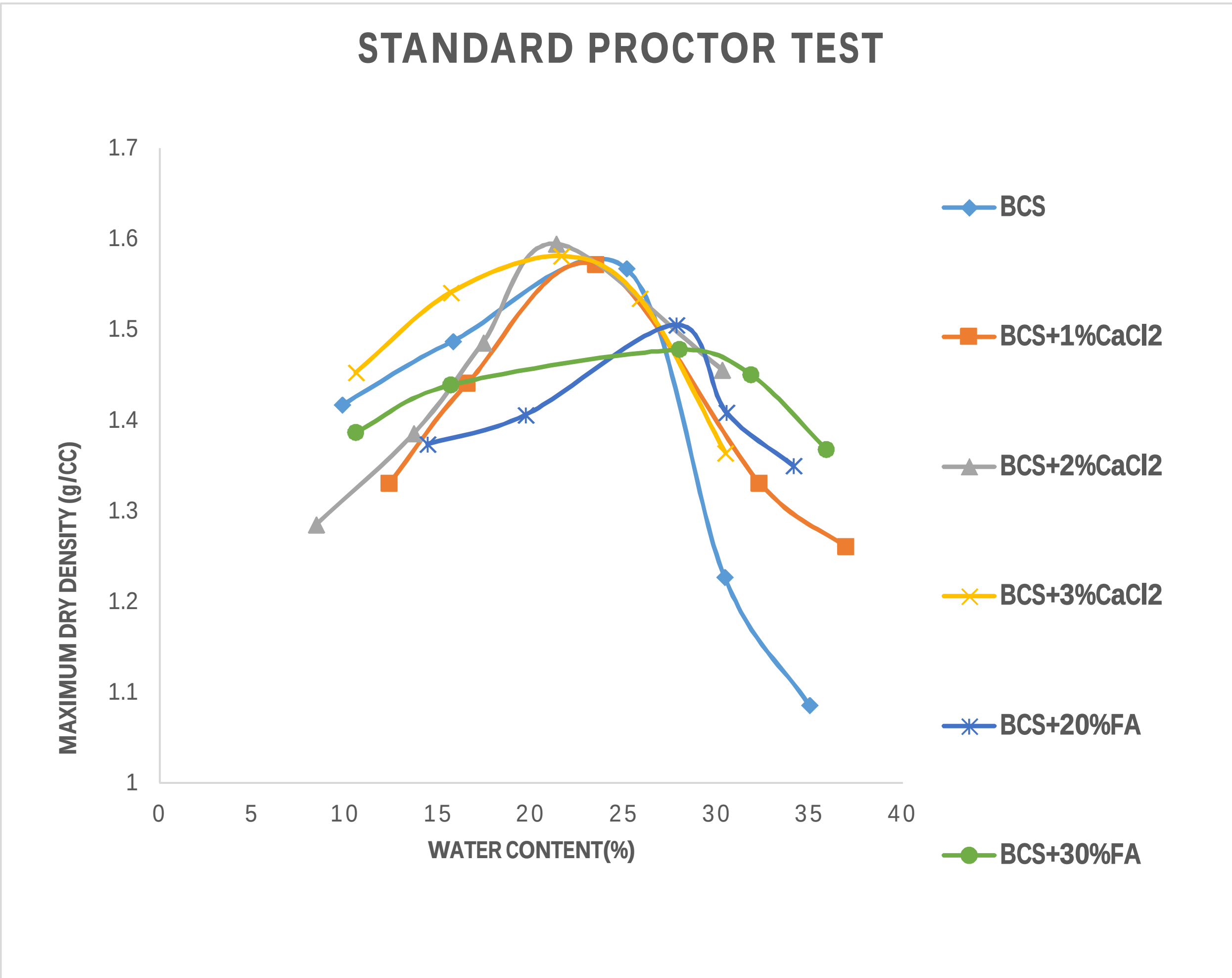

Figure 4.4 standard proctor test for different proportions of calcium chloride and fly ash

Above graph is drawn for different proportions of calcium chloride and fly ash. From the above graph it is observed black cotton soil with 3% of calcium chloride has better density and less optimum moisture content which is small margin more than of black cotton soil with 2% of calcium chloride. So for the economical point of view 2% of calcium chloride is recommended.

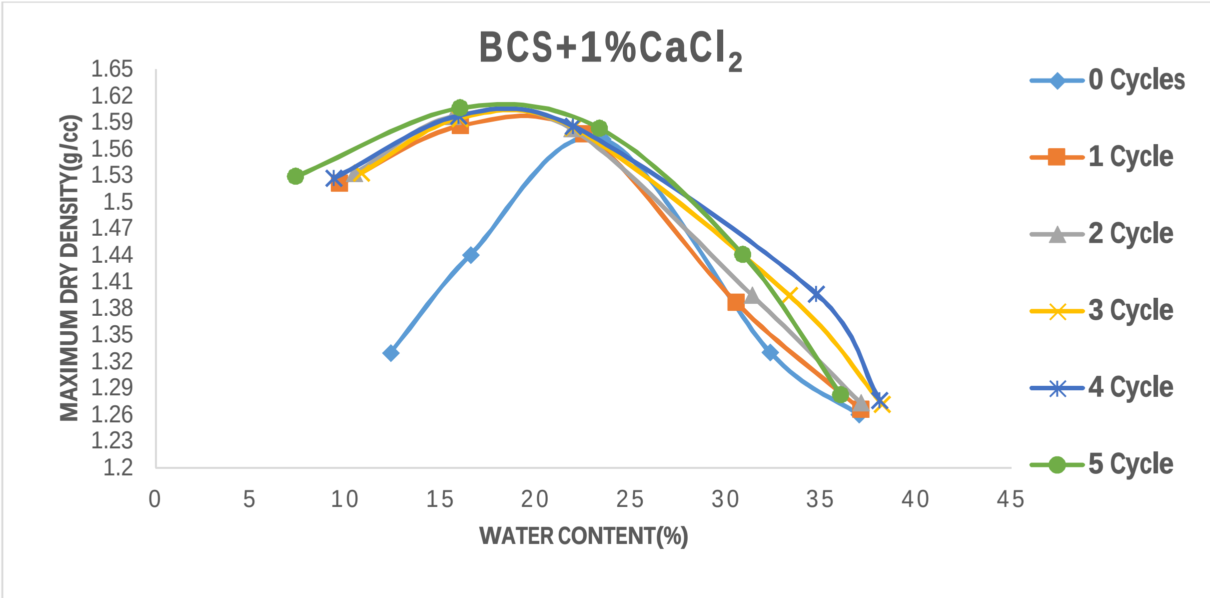

Figure 4.5 standard proctor test for different cycles of BCS+1%$CaCl_2$

And also experiments has been done for different wet and dry cycles to analyse density changes in soil it is observed that as the number of wet and dry cycles increases the density of the slightly increases.

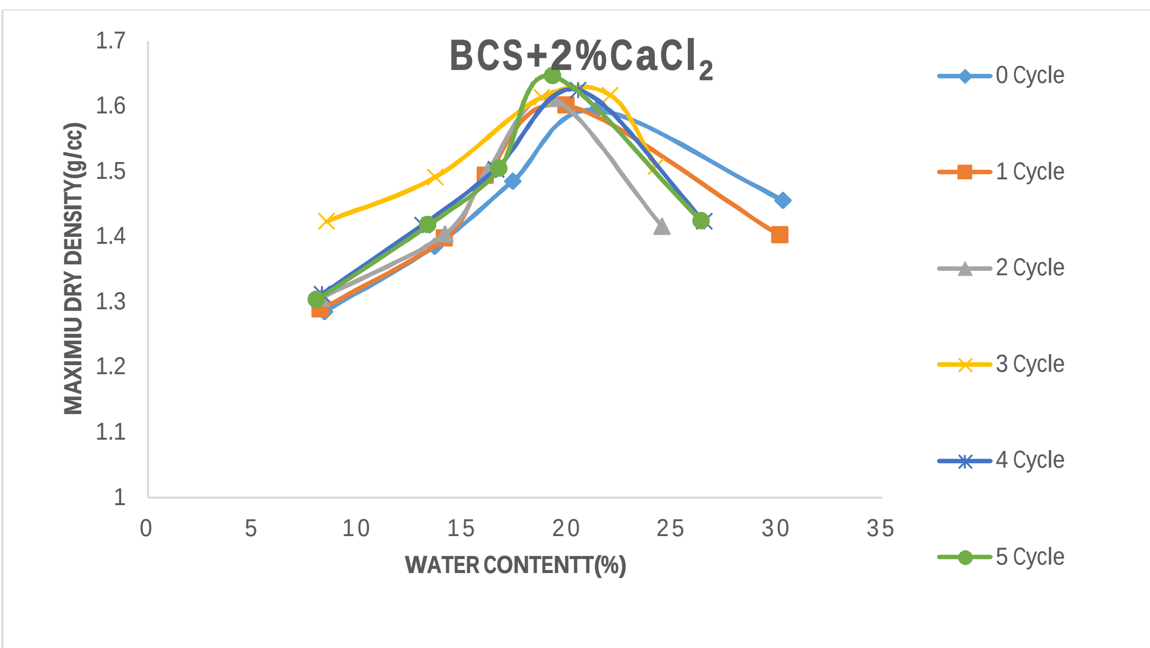

Figure 4.6 standard proctor test for different cycles of BCS+2%$CaCl_2$

The percentage of calcium chloride in this fig is 2% which is found economical in density improvement. Black cotton soil with different wet and dry cycles the dry density of the soil increases up to some extent. So for the stabilization of black cotton soil calcium chloride is recommended.

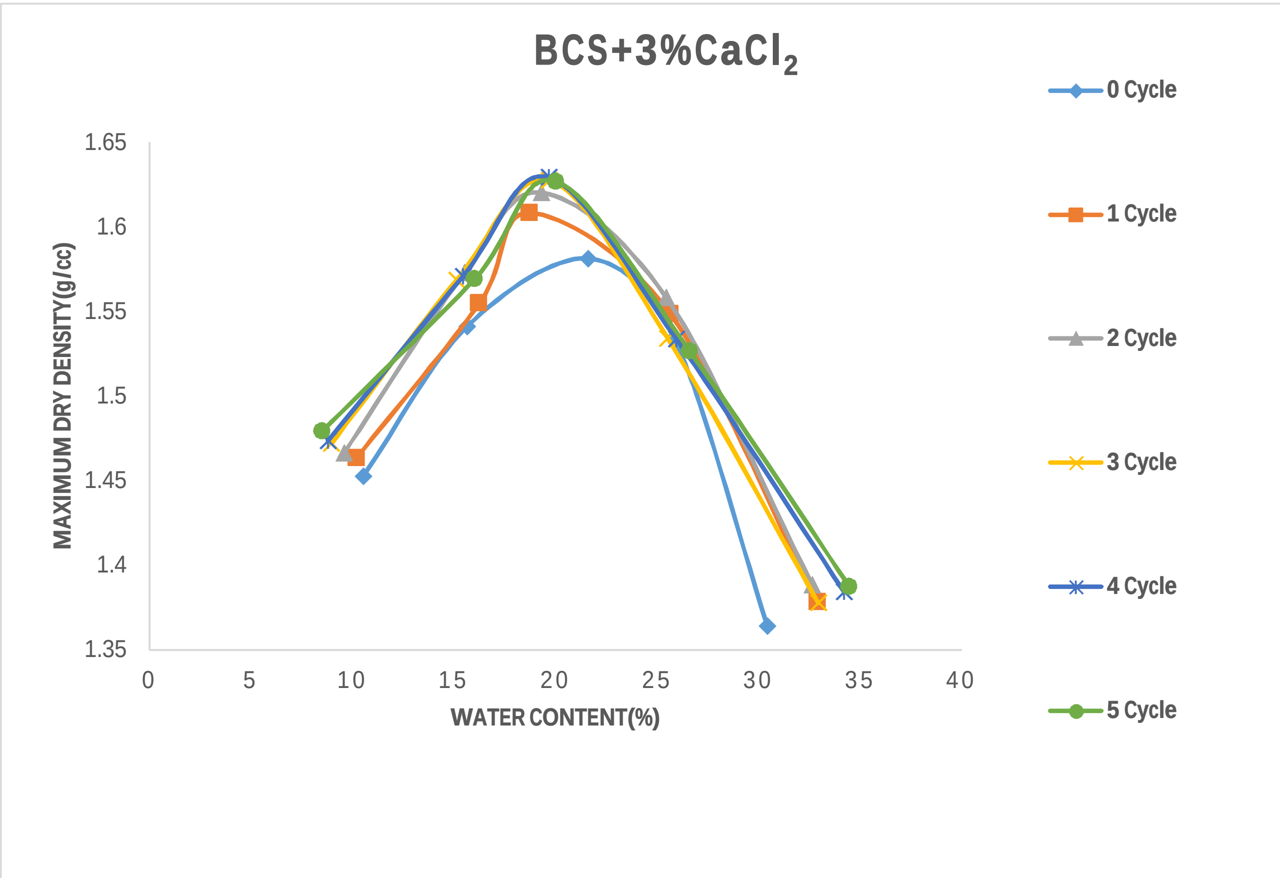

Figure 4.7 standard proctor test for different cycles of BCS+3%$CaCl_2$

From the above two graphs all the values with different percentages of calcium chloride has been observed that with 3% of calcium chloride the changes of results very small margin more than 2% of calcium chloride. So for the economical point of view 2 % of calcium chloride is recommened.

4.5 Unconfined Compressive Strength

Unconfined compressive strength has been done according to the code of IS 2720: PART 3:1980. The following results has been observed from the laboratory experiments and drawn the graphs.

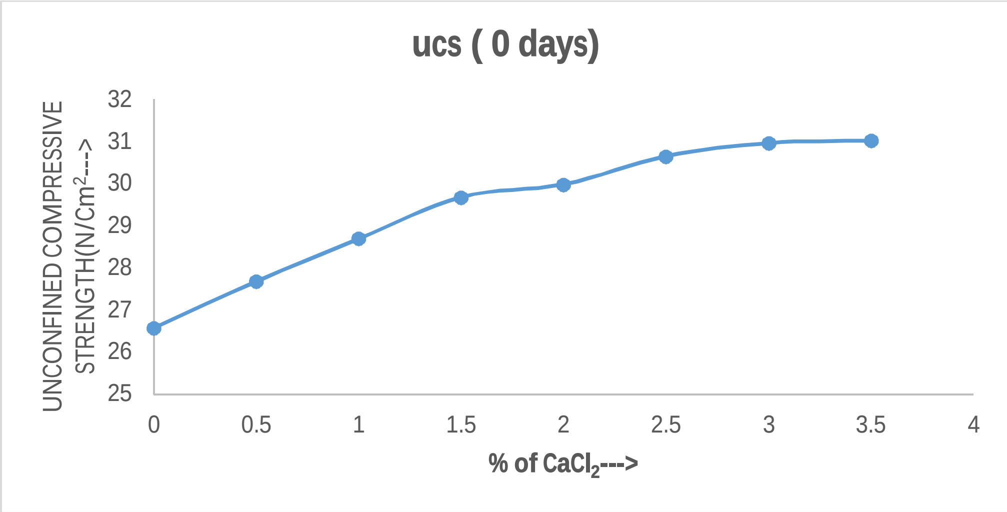

Figure 4.8 Graph between unconfined compressive strength and % of $CaCl_2$

From the above graph it has been observed that as the calcium chloride increases the unconfined compressive strength of the soil increased. Once it reached optimum value as the calcium chloride increases the unconfined compressive strength remain same or decreases.

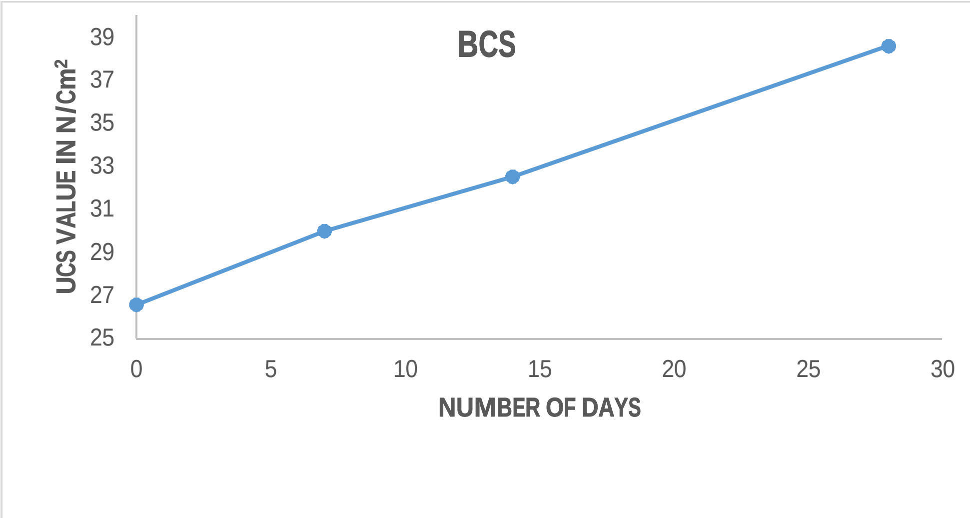

Figure 4.9 Graph between UCS value and number days for black cotton soil

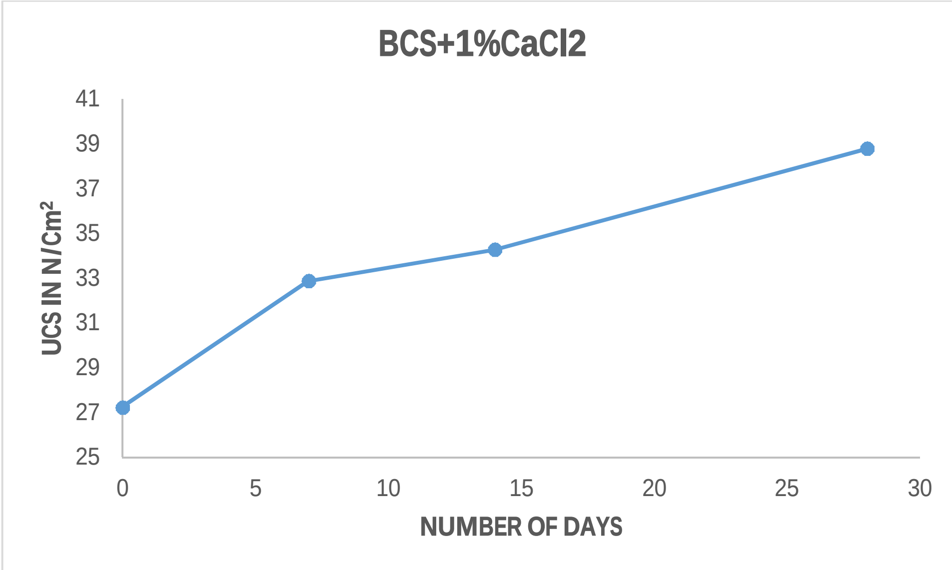

Figure 4.10 Graph between UCS value and number days for BCS+1%$CaCl_2$

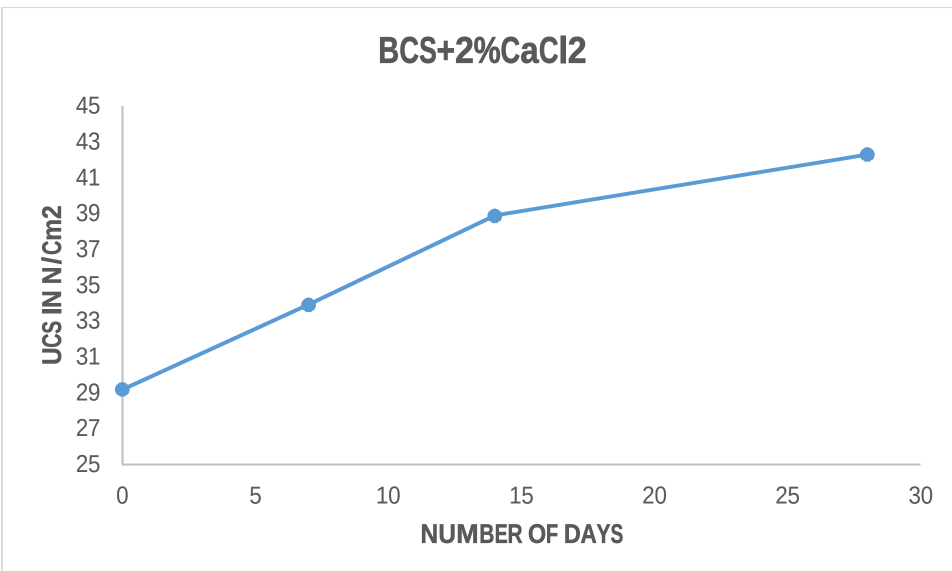

Figure 4.11 Graph between UCS value and number days for BCS+2%$CaCl_2$

From the above three graphs it has been observed that as the number of days increases the unconfined compressive strength of the soil increases. And also with increase of calcium chloride percentage the results were improved.

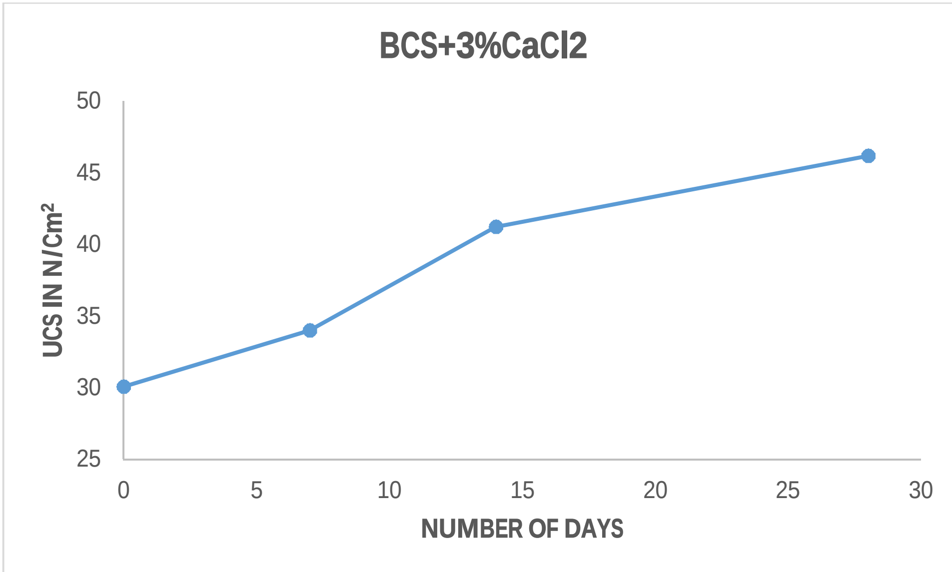

Figure 4.12 graph between UCS value and number days for BCS+3%CaCl$_2$

With 3% of calcium chloride unconfined strength results slightly more than 2% calcium results. For the economical point of view 2% of calcium chloride has been recommended.

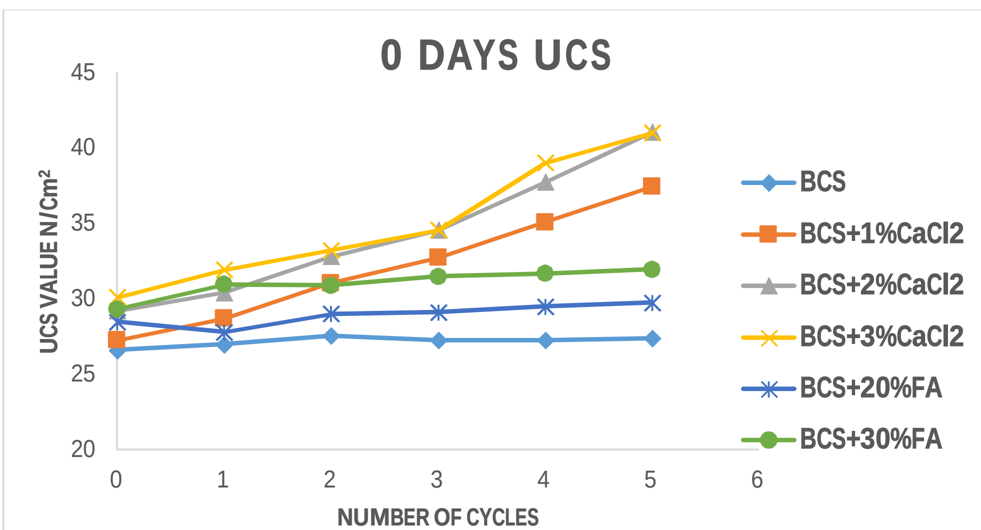

Figure 4.13 Graph between UCS and number of cycles for different proportions of CaCl2 and fly ash at 0 days

Unconfined compressive strength for 0 days has been done for different proportions of calcium chloride. It has been found that black cotton soil with 3% of calcium chloride has the better result than black cotton soil with 1% of calcium chloride. And it is observed that black cotton soil with 2% calcium chloride results slightly less than 3% calcium chloride results.

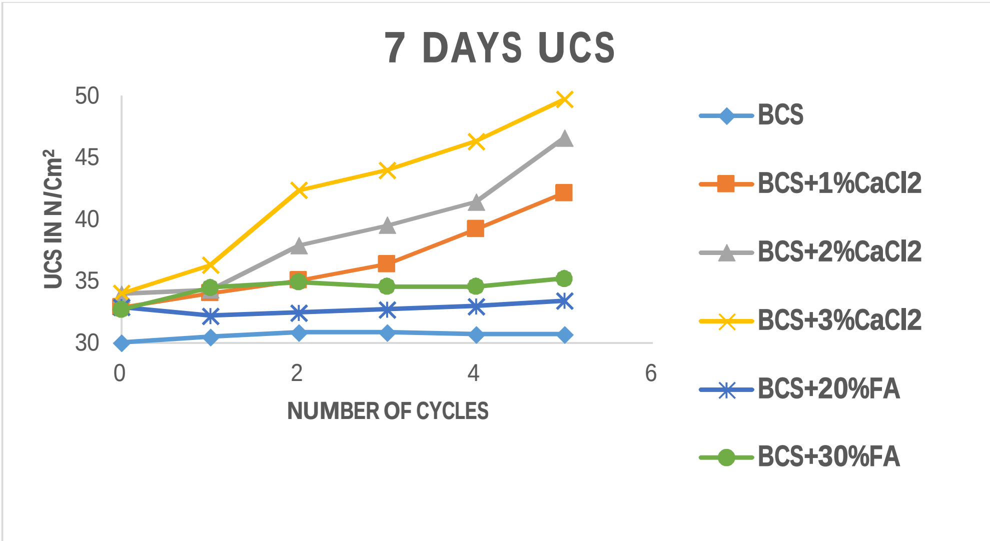

Figure 4.14 Graph between UCS and number of cycles for different proportions of $CaCl_2$ and fly ash at 7 days

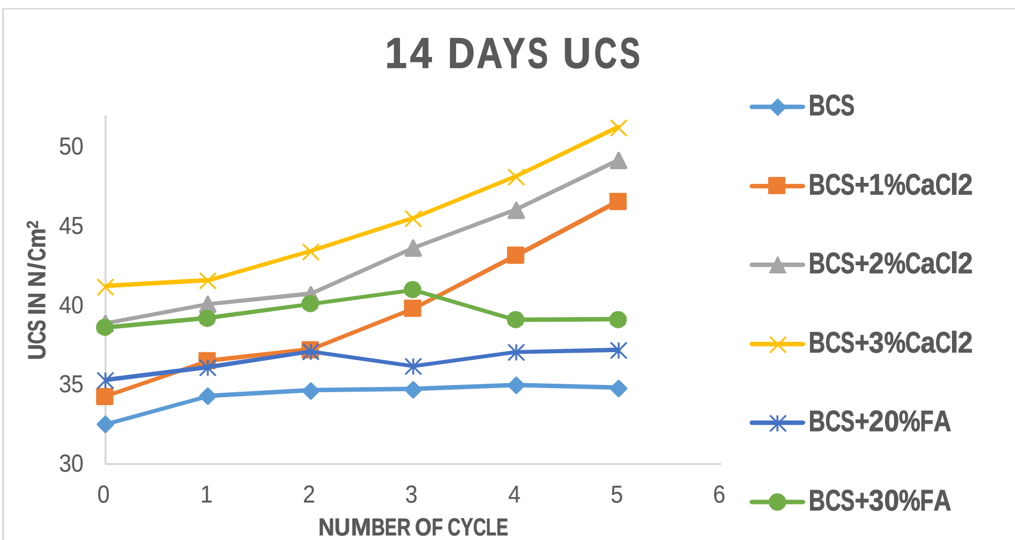

Figure 4.15 Graph between UCS and number of cycles for different proportions of $CaCl_2$ and fly ash at 14 days

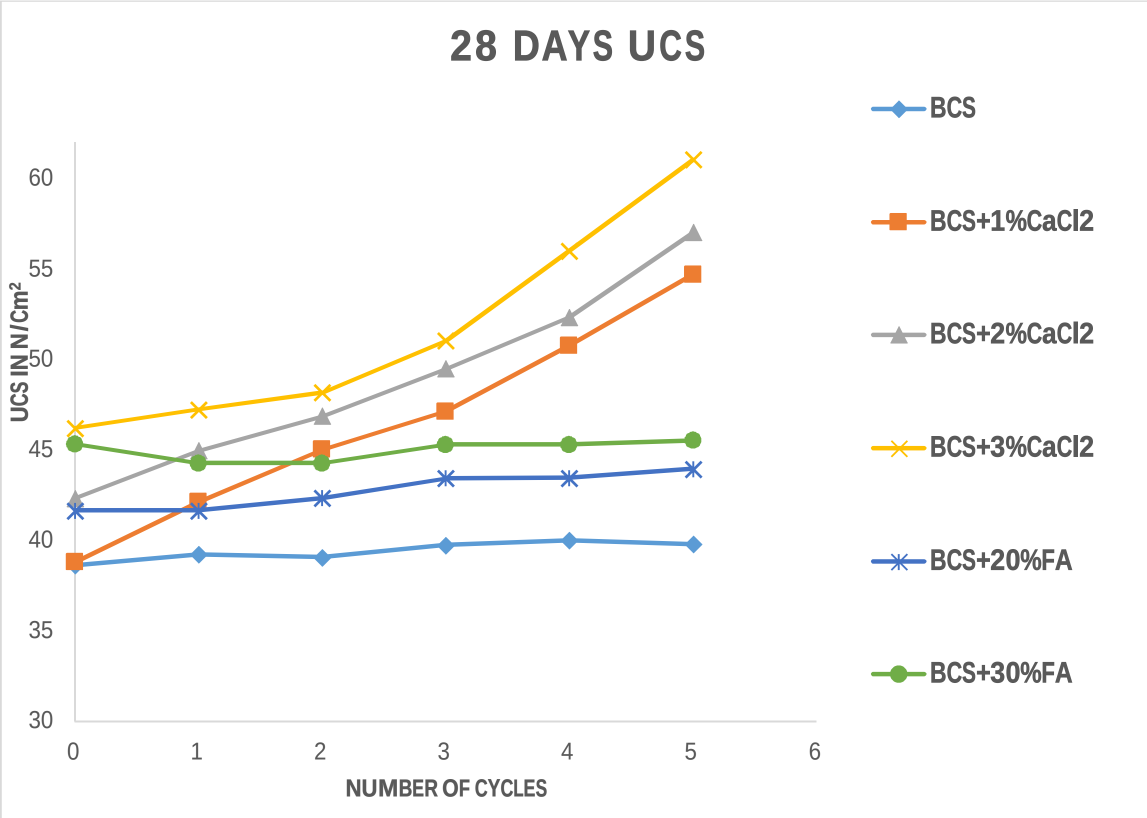

Figure 4.16 Graph between UCS and number of cycles for different proportions of $CaCl_2$ and fly ash at 28 days

The graphs were drawn for the different number of wet and dry cycles at different days. And it is observed that with increase of days the unconfined compressive strength has increased and also with increase of number of wet and dried cycles the unconfined compressive strength has increased.

From the observation of above three graphs the black cotton soil with 2% of calcium chloride is economical. Black cotton soil with 3% of calcium chloride has results slightly more than the black cotton soil with 2% of calcium chloride.

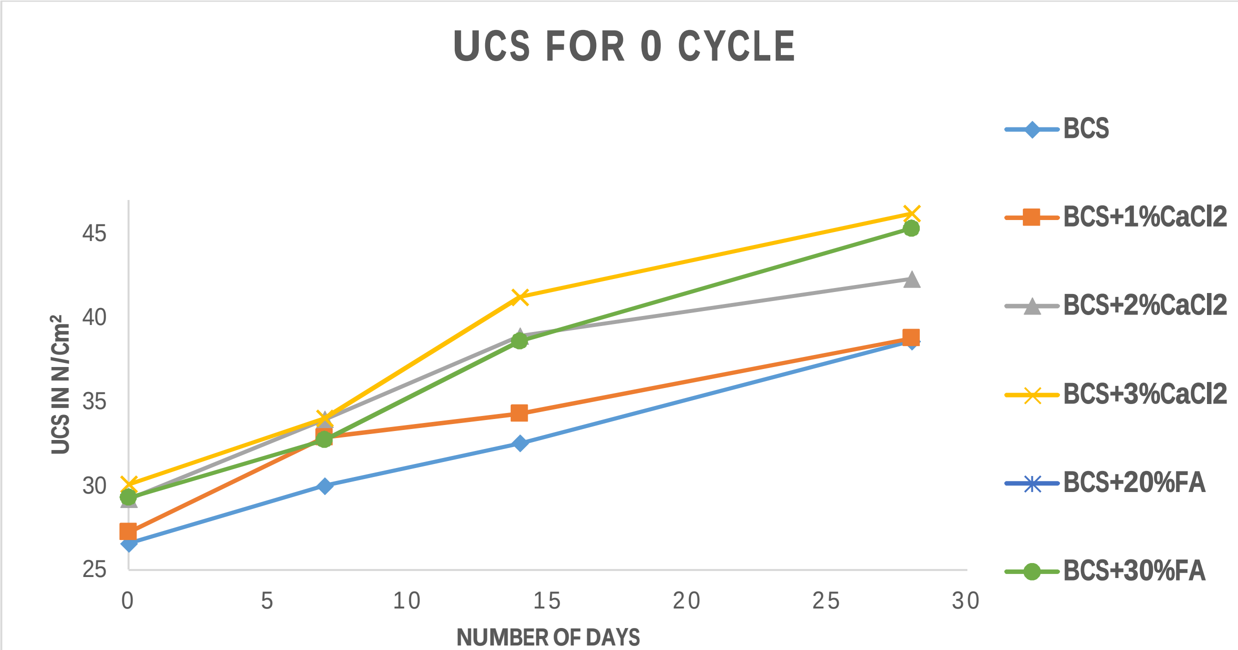

Figure 4.17 Graph between UCS and number of days for different proportions of calcium chloride and fly ash at 0 cycle

Graph is drawn between unconfined compressive strength and number of days. It is observed from the graph as the number of days increases the unconfined compressive strength increases. UCS value totally depend on the number days that the sample has cured.

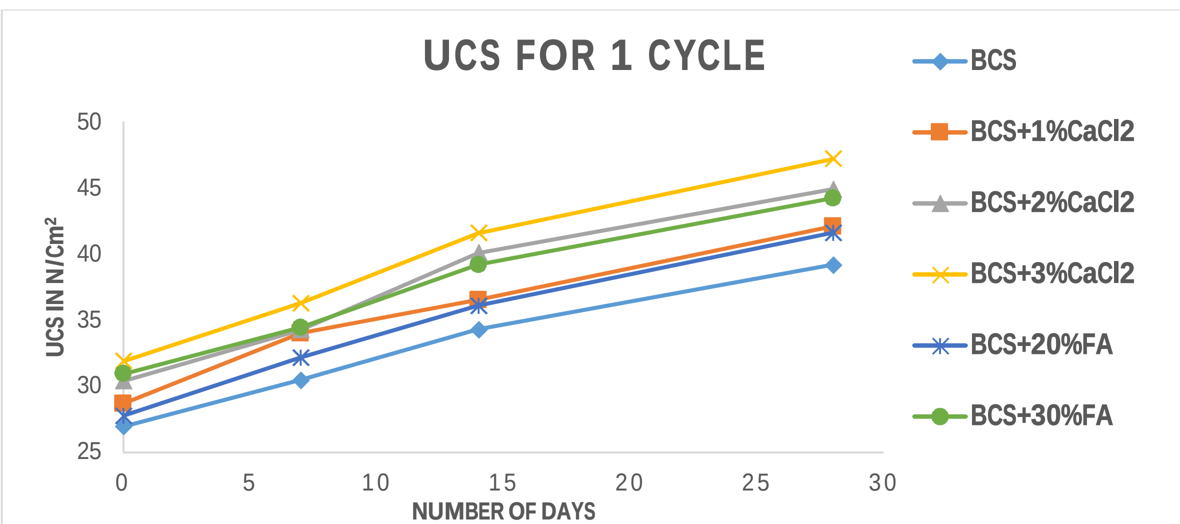

Figure 4.18 Graph between UCS and number of days for different proportions of calcium chloride and fly ash at 1 cycle

The graph shown above is drawn for the black cotton soil after subjected to one wet and dry cycles. It has been observed that the results obtained form experiments were better than the unconfined compressive strength for 0 cycles.

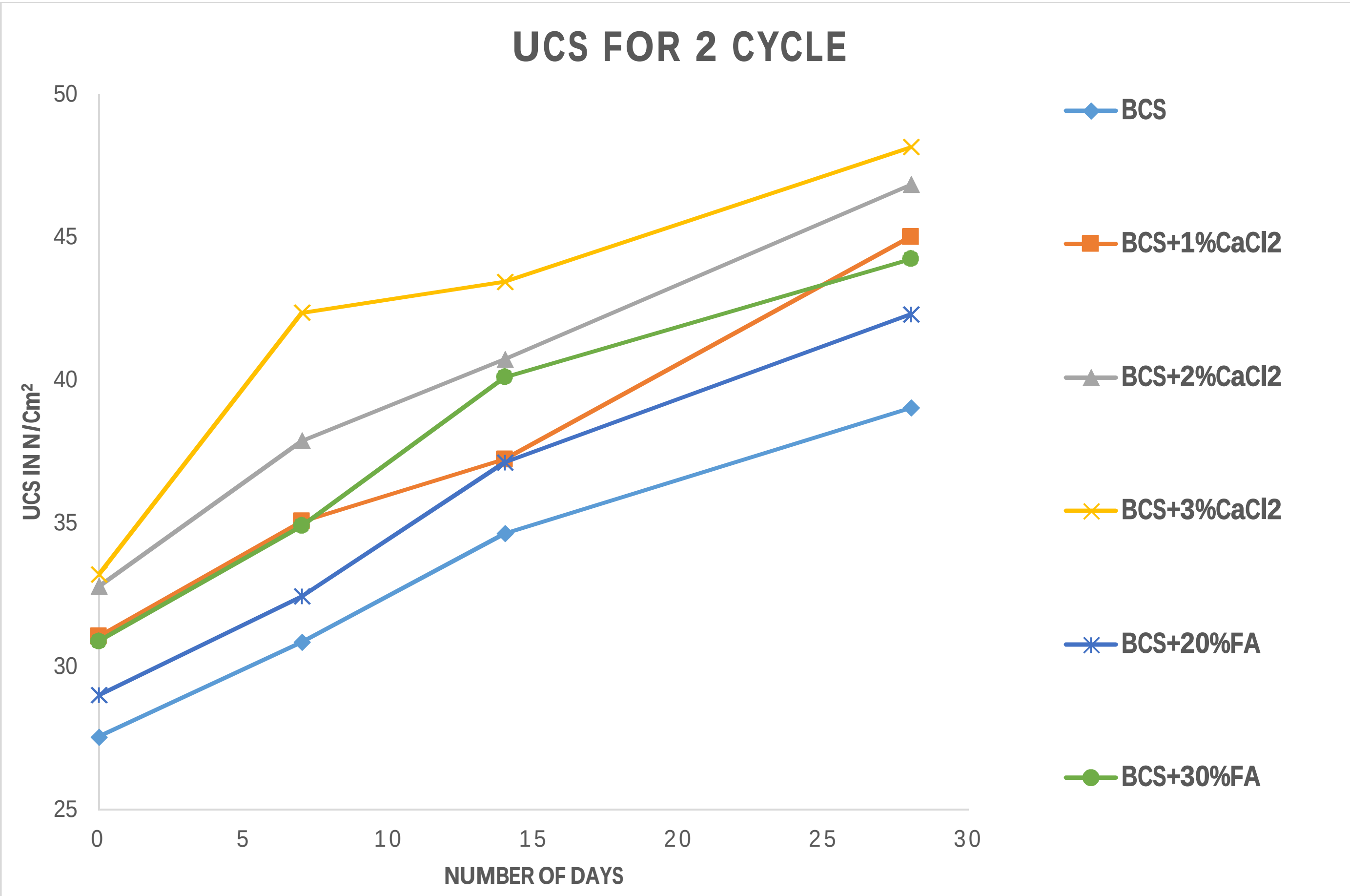

Figure 4.19 Graph between UCS and number of days for different proportions of calcium chloride and fly ash at 2 cycle

The above graph is drawn for after two number of wet and dry cycles. It has been observed that the results were more than one number of cycle. With fly ash the changes of the results negligible even after subjected to number of wet and dry cycles.

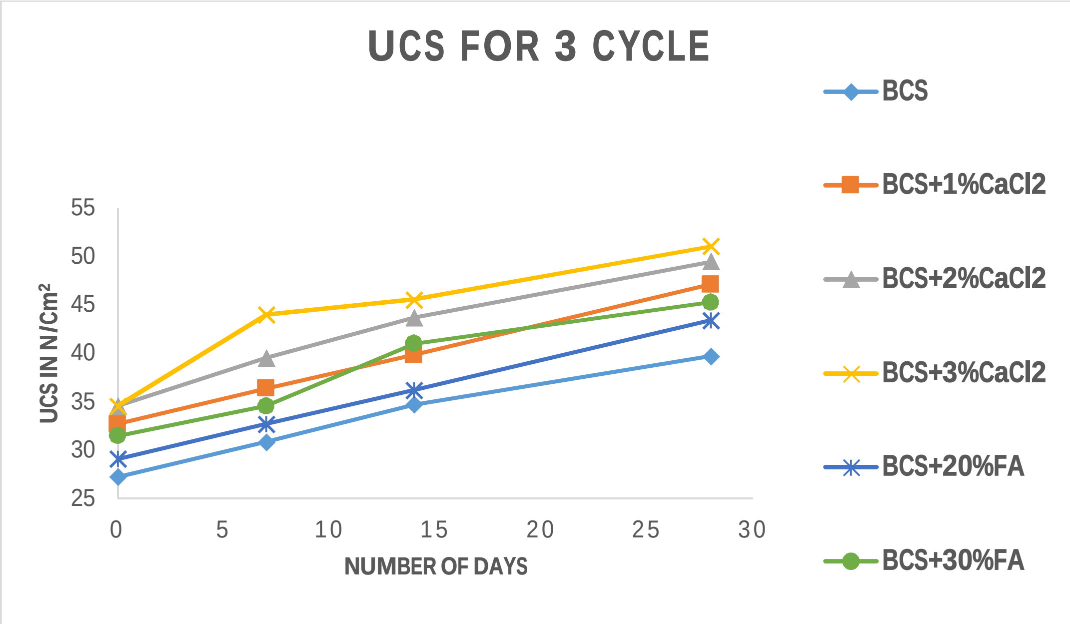

Figure 4.20 Graph between UCS and number of days for different proportions of calcium chloride and fly ash at 3 cycle

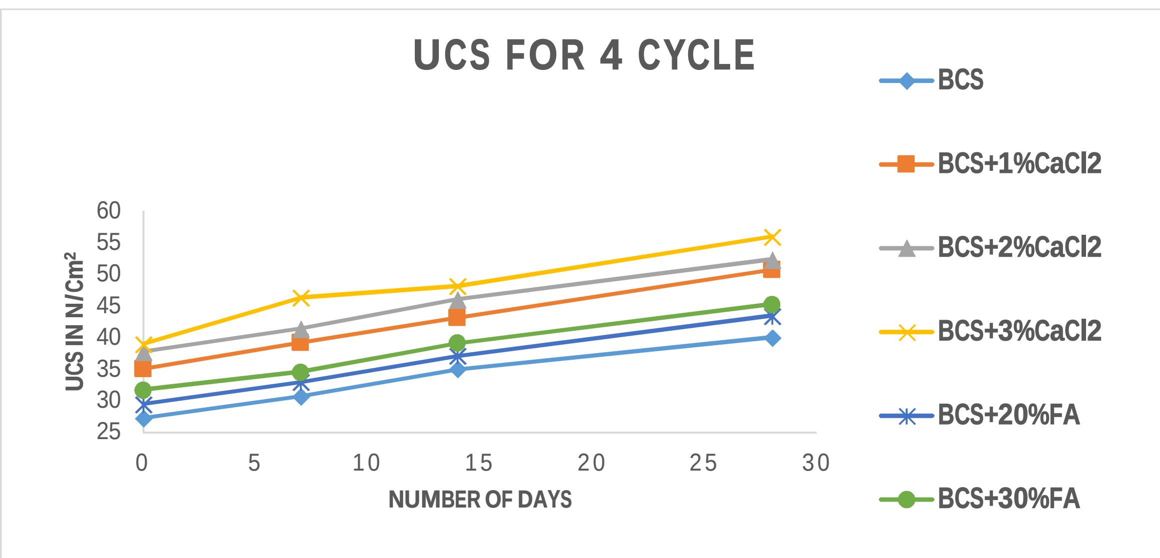

Figure 4.21 Graph between UCS and number of days for different proportions of calcium chloride and fly ash at 4 cycle

The graphs were drawn 3rd and 4th cycles. From the above it has been observed that as the number of days increases the unconfined compressive strength of the soil increases. And also as the number of cycles increases the unconfined compressive strength increases.

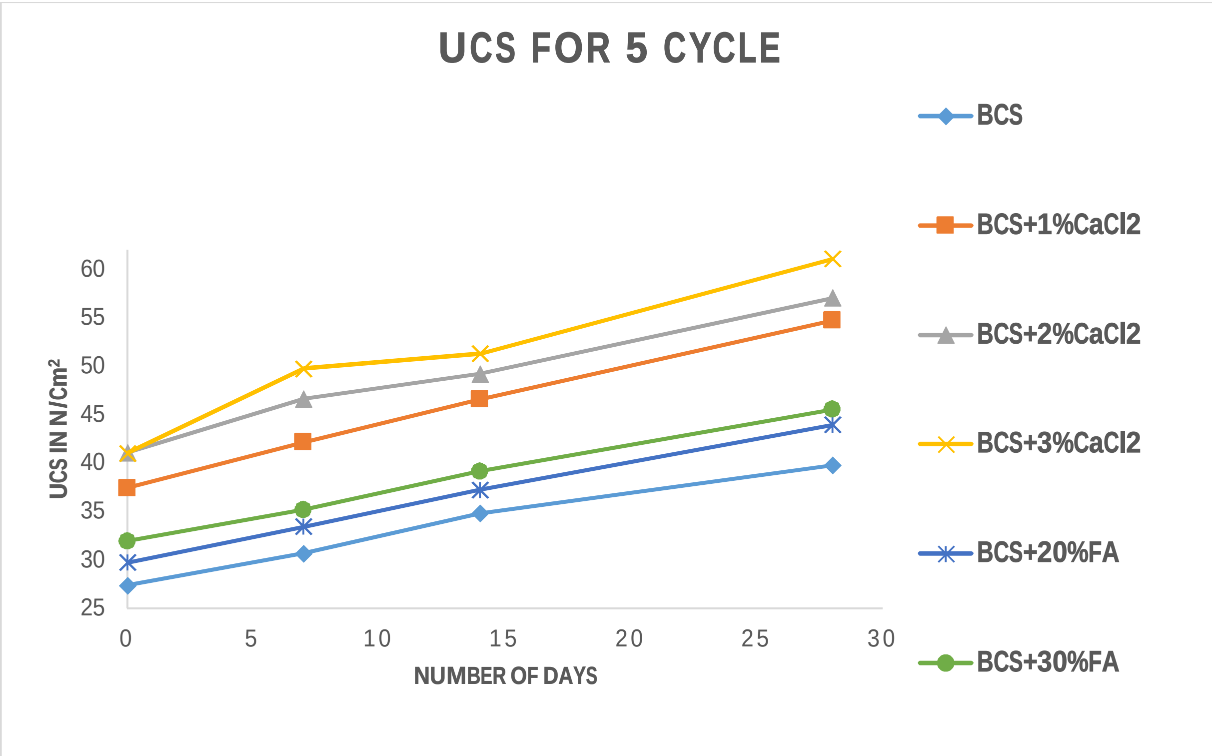

Figure 4.22 Graph between UCS and number of days for different proportions of calcium chloride and fly ash at 5 cycle

The results were observed for the 5th cycle. As the number cycles increases the increment of results has been decreasing. From the all above results it has been recommended to use black cotton soil with 2% of calcium chloride.

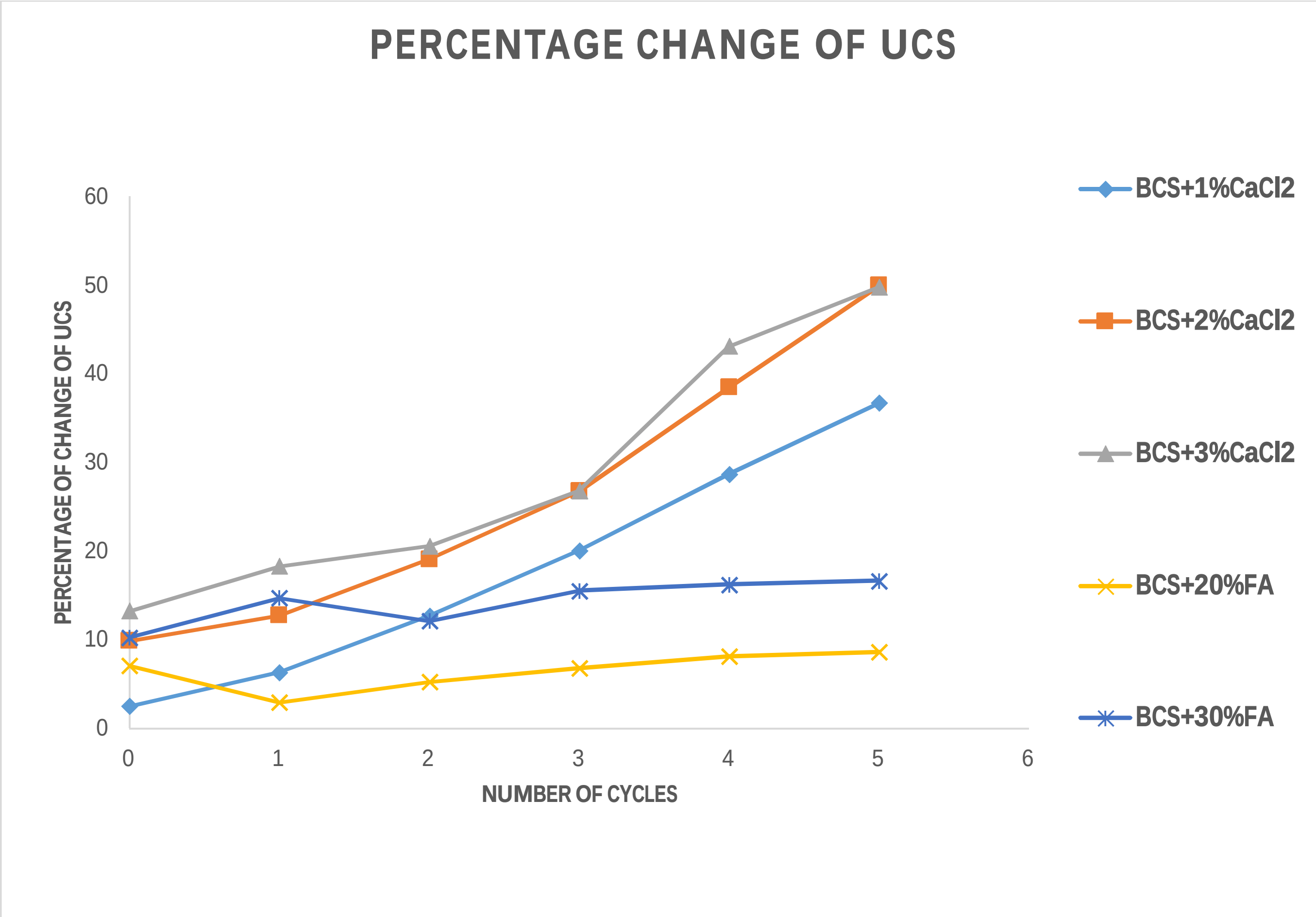

Figure 4.23 Graph between percentage change of UCS and number of cycles for different proportions of calcium chloride and black cotton soil at 0 days

Above graph is drawn for the percentage of change of UCS with number of wet and dry cycles. It has been observed that with increase of wet and dry cycles the percentage of change of unconfined compressive strength has increased.

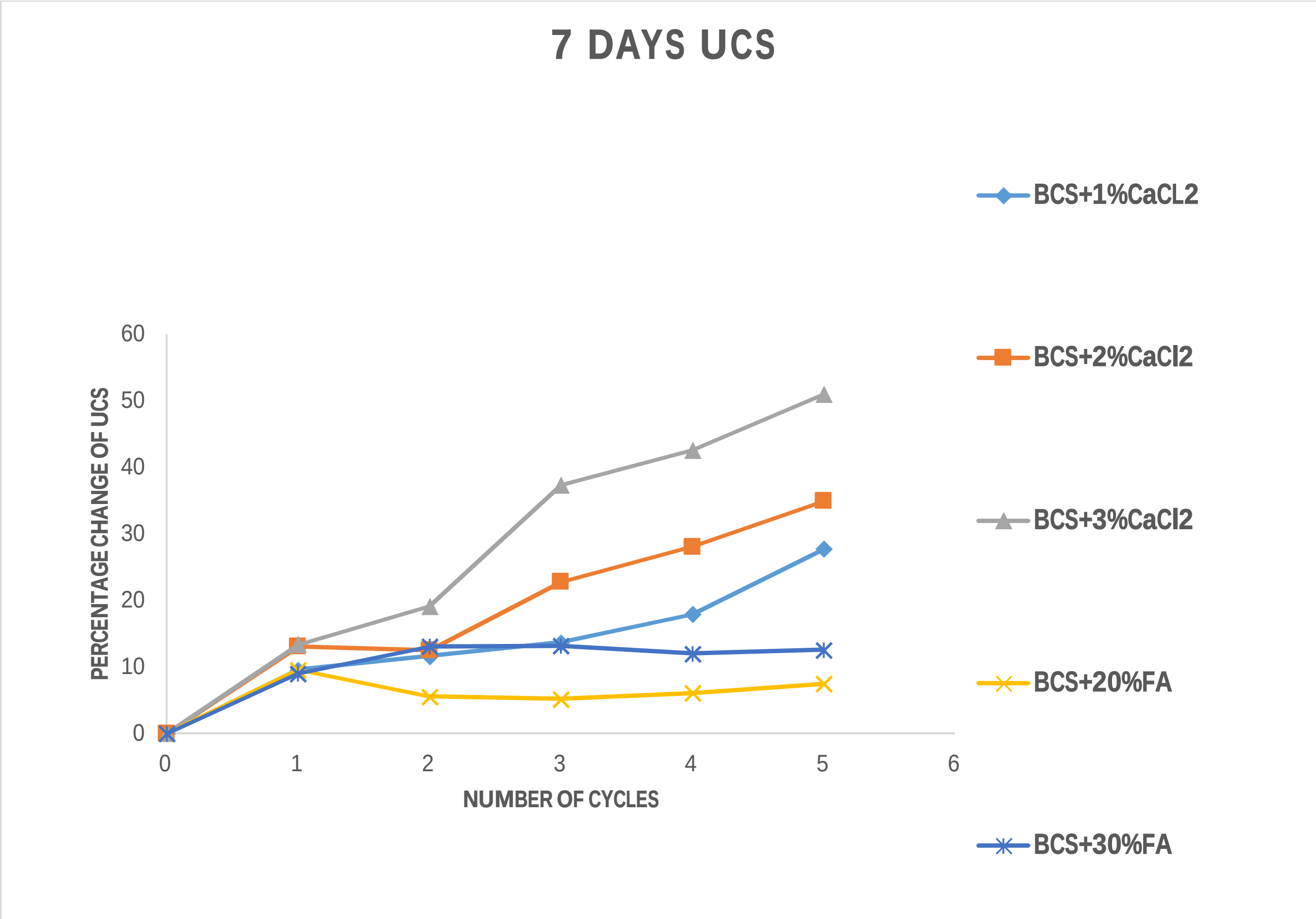

Figure 4.24 Graph between % change of UCS and number of cycles for different proportions of calcium chloride and black cotton soil at 7 day

Percentage of change of unconfined compressive strength has been drawn for number of wet and dry cycles. It has been observed that as the number of wet and dry cycled increases 7 days strength of UCS Increases. When the black cotton soil mixed with fly ash the change percentage of unconfined compressive strength constant.

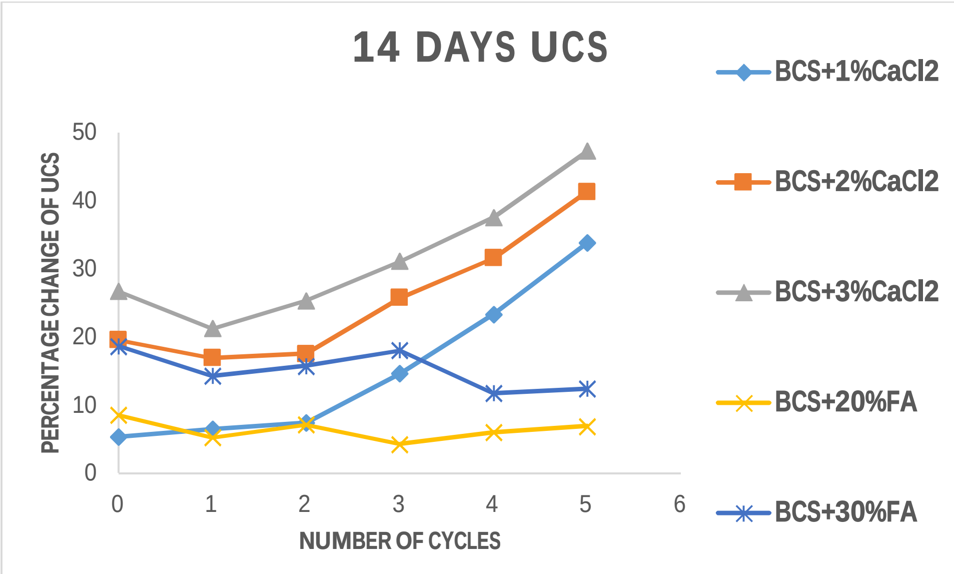

Figure 4.25 Graph between % of percentage change of UCS and number of cycles for different proportions of calcium chloride and black cotton soil at 14 days

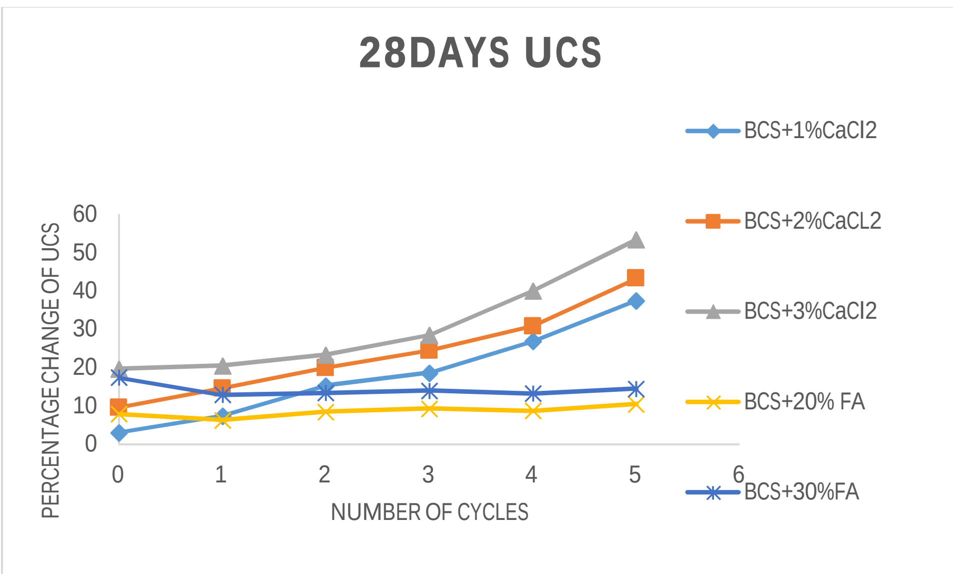

Figure 4.26 Graph between % of percentage change of UCS and number of cycles for different proportions of calcium chloride and black cotton soil at 28 day

From the above two graphs it has been observed that with increase of number of wet and dry cycles the unconfined compressive strength has been increased.

4.6 Swelling Pressure

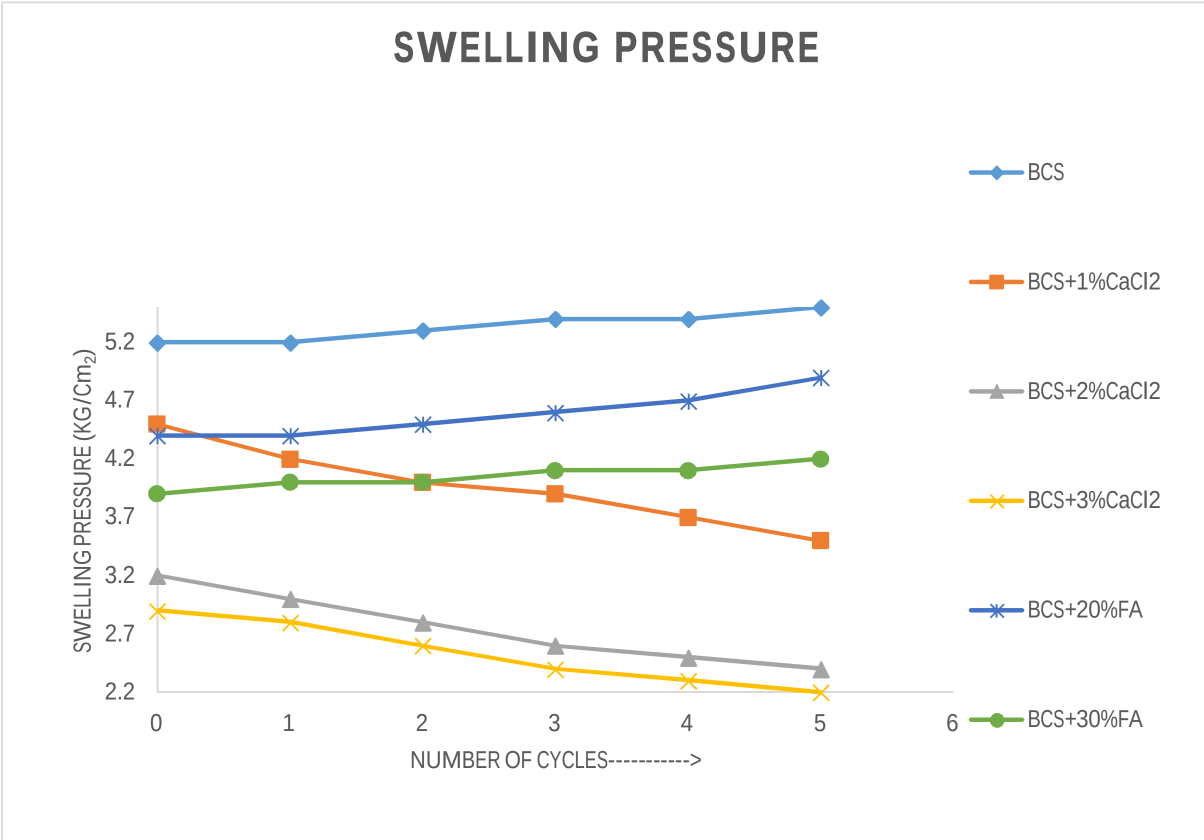

Figure 4.27 Graph between swelling pressure and number of cycles for different propotions of calcium chloride and fly ash

The graph is drawn between the swelling pressure and number of cycles of wet and dry. It has been observed that as the number of wet and dry cycles increases the swelling pressure decreases when soil mixed with different proportions of calcium chloride. And also from the above graph it is observed that black cotton soil with 3% of calcium chloride and black cotton soil with 2% of calcium chloride yielded almost same results. So for the economical point of view black cotton soil with 2% of calcium chloride has been recommended.

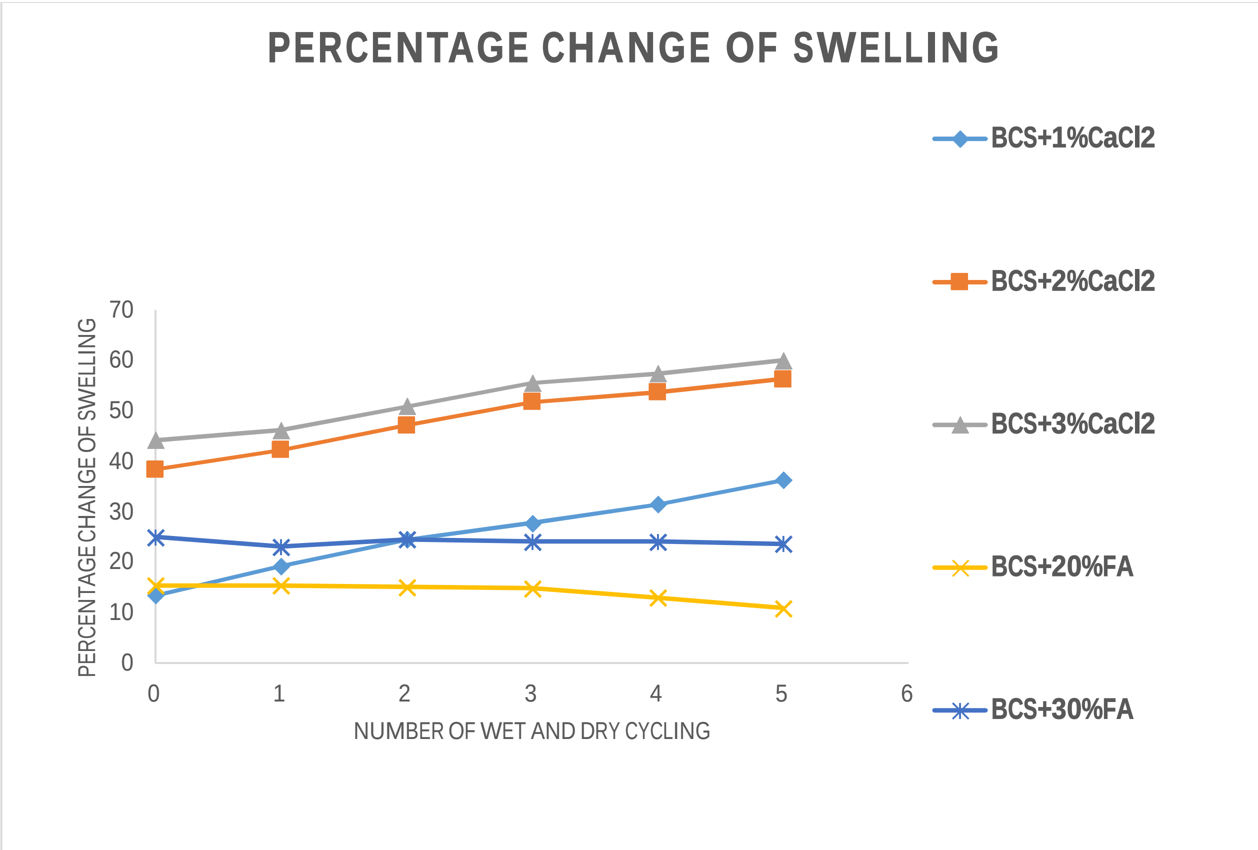

Figure 4.28 Graph between percentage reduction of swelling pressure and number of cycles for different promotions of the soil.

The graph is drawn between percentage change of swelling and number of wetting and drying cycles. It has been observed that as the wetting drying cycles increases the percentage of reduction of swelling pressure percentage increases.

Chapter-5

CONCLUSION AND SCOPE

5.1 Conclusions

Based on the experimental study and analysis of results following conclusions are made.

- Liquid limit of the soil decreases with change of calcium chloride percentage. Thus with increase in calcium chloride cation exchange of the soil increases.
- Liquid limit also decreases with number of wet and dry cycles so we can conclude full cation exchange capacity does not takes place instantly after adding to the soil.
- Plastic limit of the soil increases with change of calcium chloride percentage so we can conclude that plasticity index of the soil decreases, so the swelling characteristics also decreases.
- UCS value of the soil increases with increases of calcium chloride. The UCS results of 3% $CaCl_2$ and black cotton soil slightly above the results of 2% $CaCl_2$ and black cotton soil. So economically 2% calcium chloride has been recommended for stabilization of soil.
- UCS values increases with increase of number of days of curing. And also increases with increases of wet and dry cycles.
- The swelling pressure value of the soil decreases with increases of calcium chloride. The swelling pressure results of 3% $CaCl_2$ and black cotton soil slightly lower than the results of 2% $CaCl_2$ and black cotton soil. So economically 2% calcium chloride has been recommended for stabilization of soil.

5.2 Future Scope

Efforts should be made to obtain less cost material for the cation exchange in the place of calcium chloride.

- Field application of this method by the suitable technology
- Use of other chemical their effect on the cation exchange of the black cotton soil.
- Application of this calcium chloride for other highly expansive soil materials.

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